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Proceedings of the NASA Workshop on Flight Deck Centered Parallel Runway Approaches in Instrument Meteorological Conditions

*Edited by
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Langley Research Center • Hampton, Virginia*

Proceedings of a workshop sponsored by the
National Aeronautics and Space Administration,
Washington, D.C., and held at
NASA Langley Research Center,
Hampton, Virginia
October 29, 1996

December 1996

Foreword

Many U.S. airports depend on parallel runway operations to achieve capacity necessary for day to day operations. In the current airspace system, Instrument Meteorological Conditions (IMC) reduce the capacity of parallel runway approach operations spaced closer than 4300 ft. apart, or 3400 ft. where Precision Runway Monitoring (PRM) is applicable. The lost capacity costs the airline industry hundreds of millions of dollars each year. Its impact on other businesses and personal inconveniences to travelers is significantly costly but difficult to quantify.

A Government and Industry Workshop on Flight-Deck-Centered Parallel Runway Approaches in IMC was conducted October 29, 1996 at the NASA Langley Research Center, Pearl I. Young Theater. This document contains the slides and records of proceedings at the workshop. The purpose of the workshop was to disclose, to the national airspace community, the status of ongoing NASA Research and Development (R&D) to address the closely spaced parallel runway problem in instrument meteorological conditions and to seek advice and input on the direction of future work to assure an optimized research approach. This research is entitled Airborne Information for Lateral Spacing (AILS).

The workshop highlighted results of focused NASA R&D to develop a practical solution to IMC approaches to closely spaced parallel runways. NASA simulation studies have shown promising results for parallel approaches spaced as close as 1700 ft. apart. Implementation in the field will require capabilities such as will be provided by Automatic Dependent Surveillance-Broadcast (ADS-B) and local Differential Global Positioning Systems (DGPS). The intent of this R&D is to provide a concept that will complement the capabilities developed in the FAA's PRM program, to safely accomplish even closer parallel runway approaches. The technology envisioned includes enhancements to current Traffic Alert and Collision Avoidance System (TCAS) technology and navigation capabilities in the flight deck to enable airborne crews to assume responsibility for lateral path compliance and separation during closely spaced parallel approaches.

To date, NASA has completed three simulation studies and has scheduled initial flight testing to further develop and evaluate related technologies during fiscal year 1997. These studies and plans were discussed by Marvin Waller of Langley, Trent Thrush of Ames, and Charles Scanlon of Langley.

The workshop also included a discussion by Rocky Stone of United Airlines (UAL) of plans to explore the use of dependent parallel approaches described as "paired approaches." This concept was first investigated at NASA Langley in 1994 and discussed in a presentation to RTCA SC-147 in June 1995 (Ref. RTCA Paper No. 346-95/SC147-634, July 14, 1995), as a "Staggered Pair Concept." The adaptation by United Airlines has added cooperating pairs of company airplanes to address the delay

dilemma at the San Francisco International Airport (SFO) where the parallel runway separation is 750 feet. Rocky Stone is leading the effort at UAL.

In a presentation describing work closely related to AILS, Gene Wong, FAA AND-450, presented a discussion of the status of the FAA PRM Program that has been successful in enabling close parallel runway operations down to 3400 feet lateral runway spacing. Also, David Hinton of NASA Langley discussed NASA's plans to investigate the implications of wake vortices on closely spaced parallel runway operations in IMC.

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NASA AILS Research Executive Summary

Airborne Information for Lateral Spacing is an effort within the Reduced Spacing Operations (RSO) element of the Terminal Area Productivity (TAP) Program at NASA. The TAP program is led by Robert Jacobsen at NASA Ames and the RSO element is led by Brad Perry at Langley.

The objective of the AILS research being conducted at the Langley Research Center and at the Ames Research Center is to enable approaches to closely spaced parallel runways in IMC with a capacity similar to that obtained in VMC. This research is examining options to enable airborne crew responsibility for aircraft separation during closely spaced parallel approaches. The initial focus of the NASA work has been on independent parallel approaches with intentions of investigating dependent concepts as time and resources permit.

Langley and Ames have planned a number of studies to address the problem, with Langley leading in this activity. A concept design team has been assembled to address the problem. The team at Langley has designed an initial concept after concluding that the problem of flying parallel approaches has two major components. The first is to provide accurate navigation for aircraft on the closely spaced parallel approach paths and to provide alerts to help keep intrusions from occurring. The second is to provide adequate protection for aircraft should one aircraft deviate from its assigned airspace in a manner that threatens another aircraft on a parallel approach path. The research at Ames has focused on providing TCAS like display guidance during collision avoidance maneuvers. The AILS work to date has addressed parallel pairs as opposed to parallel triplets or quadruplets, since it presents a simpler, yet real problem with significant payoff potentials.

Figure 1 illustrates technology that could potentially be used to implement the concept. DGPS provides the basis for the accurate navigation required to perform the approach, while ADS-B, currently under development, will enable aircraft to broadcast their position and other state information such as position, track, and rate of turn. Other aircraft will receive the transmitted information and maintain an accurate fix on aircraft operating on a parallel approach. In addition, the transmitted state information will provide an indication of whether the traffic is turning away from its course or headed back to its nominal path.

As mentioned above, this concept focuses on two aspects of the problem. One aspect is to provide accurate navigation to keep aircraft in their own assigned airspace along the approach paths and keep aircraft from threatening others. Langley engineers are investigating whether the conventional localizer path can be replaced with capabilities such as DGPS to provide parallel approaches where there is less potential for path overlap. Langley is currently exploring use of what is referred to as a "rocketship" shaped lateral path approach profile. The two dot localizer deviation profile resembles a rocketship in its plan view and was suggested by Charles Scanlon of the concept

design team. In the area of “localizer capture,” the two dot deviation is 2000 ft. on either side of the extended runway centerline. Also, as is normal for parallel runway operations, the approach paths are separated by 1000 ft. altitude during localizer capture. At about 12 miles from the runway threshold, the path width begins to taper down to 400 ft. on either side of the extended runway centerline at 10 nautical miles. After the 400 ft. half-width area is entered, the higher aircraft starts to descend and altitude separation is given up. The 400 ft. half width of the path is held from that point to a location near middle marker where a conventional localizer angular beam shape and width are captured (using DGPS to emulate the conventional localizer signal).

An alerting feature has also been incorporated in the concept to prevent aircraft from straying from their airspace. Should an airplane deviate one dot or more from its nominal path, a caution or level two (SAE ARP-450D) alert is issued to the deviating aircraft with displayed information presented in amber alphanumeric and symbolic formats in the primary flight display and in the navigation display, to warn the flight deck crew to maintain a tighter path adherence. Should an aircraft deviate two dots or more from the prescribed path, a level three alert is issued (using red colors for the displayed information), requiring a break-off maneuver in the direction away from the parallel traffic. In the version of the Langley concept implemented for the second phase of testing, depending of the severity situation, level two or level three alerts are also used to prevent one aircraft from threatening another with excessive bank angles or tracks. The current Langley concept requires use of a single, identical break-off maneuver for all parallel approach deviations. The aircraft required to break off the approach must execute an emergency escape maneuver consisting of a turning climb to a heading 45 degrees away from the nominal runway heading, in the direction away from the parallel approach traffic. A heading bug is automatically set to the (45 degree) escape heading when the alerting algorithms are armed in the approach sequence.

The second aspect of the Langley version of the AILS concept addresses procedures to avoid collisions and near misses in the event one aircraft strays from its airspace and approaches the path of another in a threatening manner. An onboard alerting algorithm will use state information from traffic on the parallel runway, transmitted by the ADS-B link, to detect threatening aircraft and provide an onboard alert to the flight deck crew. The alert is again presented in the primary flight display and the navigation display. A caution is presented in amber as the alerting system first detects the threat as it starts to evolve. As the danger becomes more imminent based on the computations associated with the alerting algorithms, a red (level three) alert is issued in the flight deck of the protected aircraft. The (amber) caution alert and the (red) warning alert in the configurations under study at Langley are accompanied by specially designed displays of the threatening airplane's path to allow the flight deck crew to quickly assess the nature and severity of the threat. In the concept, the red alert, a level three, requires the flight deck crew to execute the emergency escape maneuver as described above. Again this is an immediate, accelerating, climbing turn away from the approaching traffic and parallel runway to a heading of 45 degrees from the nominal approach heading. The version of the concept under study at Langley displays information in the primary flight display and in the navigation display. A computer

controlled voice message complements the displayed information with a “Turn, Climb. Turn, Climb. Turn, Climb” aural advisory when the level three alert is activated.

The concept design team at Langley completed a fixed base simulation test of the initial concept in May 1996. In the test, sixteen pilots each flew 56 parallel approaches, with about one third of the cases presenting collision or near miss threats. The test subjects were line pilots from a number of airlines and air-freight companies. They were trained for the task as they are trained and tested for, e.g., rejected takeoffs (RTO's), and category II approaches. The reaction time of the pilots in executing the turning maneuver and the closest approach were key parameters measured in these tests. Parallel approaches spaced 3400 and 2500 feet apart were examined in the initial study. The test findings show that, under the conditions tested, all of the pilot reaction times were well under the two seconds targeted by the NASA design team, and that no trials resulted in violations of the 500 ft. minimal separations used for defining near misses in the parallel runway approach environment. The mean miss distance measured was in excess of 1900 ft., with the closest encounter of 1183 ft.

A second phase of testing was completed in July 1996 at Langley. The follow-up tests included new alerting algorithms and modifications to the displays based on observations and pilot comments from earlier tests. Runway lateral spacing was reduced to 1700 ft. and 1200 ft. Eight two-member airline crews were tested in the second phase. The results were very promising for the 1700 ft. runway separation, with no encounters closer than the targeted 500 ft. miss criteria. The 1200 ft. case resulted in one encounter closer than the 500 ft. two dimensional near missed criterion used and is regarded as questionable by the design team, when the current experimental AILS technology is used.

The study at NASA Ames Research Center was completed in August 1996 and explored application of TCAS concepts to the closely spaced parallel runway approach problem. This study showed that a display based on the TCAS formats, but enhanced with a higher resolution navigation display and specially designed alerting algorithms, resulted in better performance than the TCAS implementation using a conventional navigation display format. The performance with the enhanced display features and alerting algorithms resulted in no near misses and good pilot evaluations. The study at Ames investigated an autopilot coupled approach, in contrast with the manual mode used in the Langley studies, and addressed the 4300 ft. and 2500 ft. runway spacing cases.

In interpreting these results it is important to realize that they show the feasibility of the AILS concept in initial testing in a research simulator environment and that a large amount of additional testing and validation is required before a concept of this nature could be implemented in the national airspace system. Among the issues that must be resolved is the effects of wake vortex considerations.

For additional information, contact Brad Perry 757-864-8257, Marvin Waller 757-864-2025, or Charles Scanlon 757-864-2034.

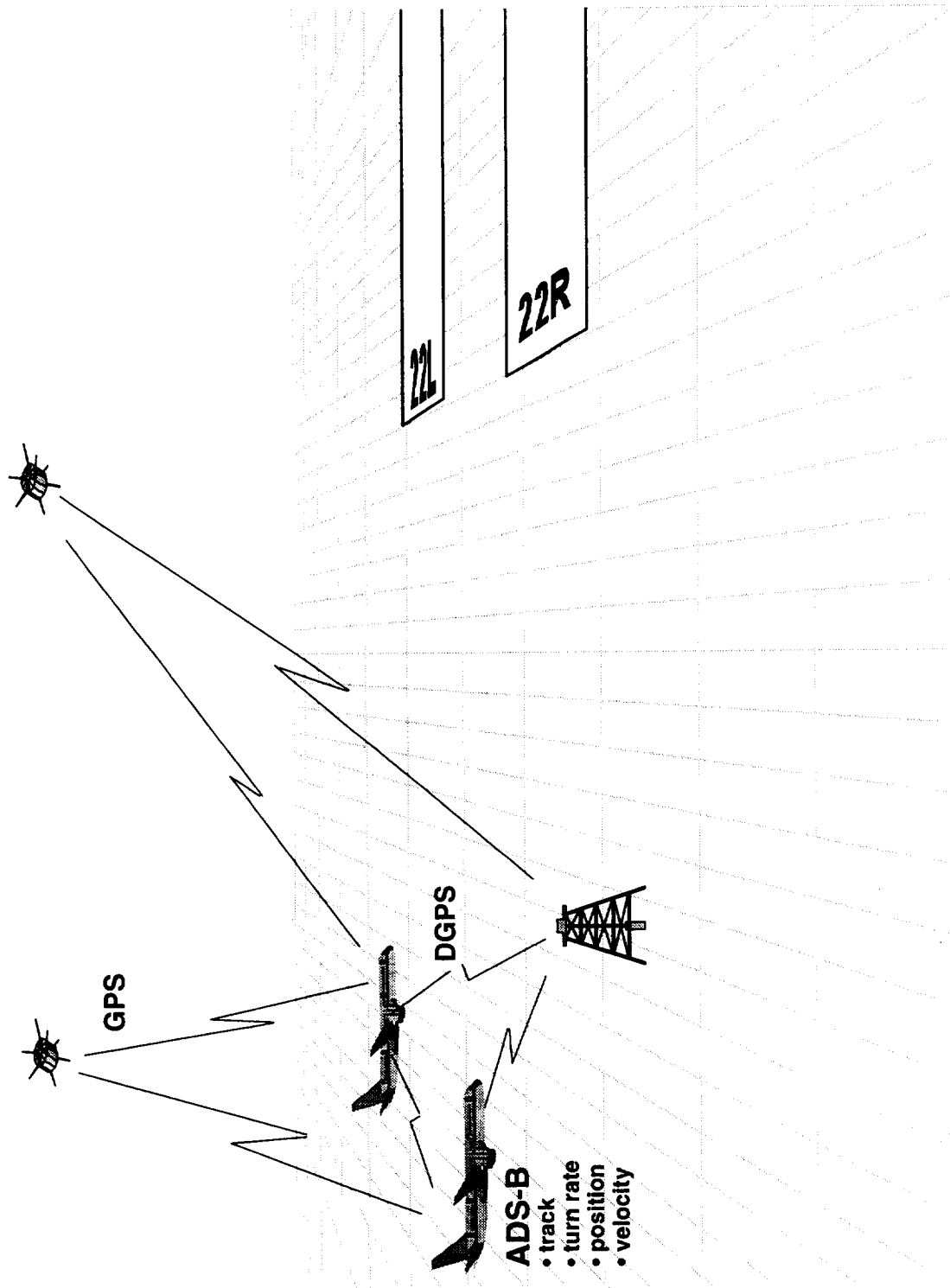
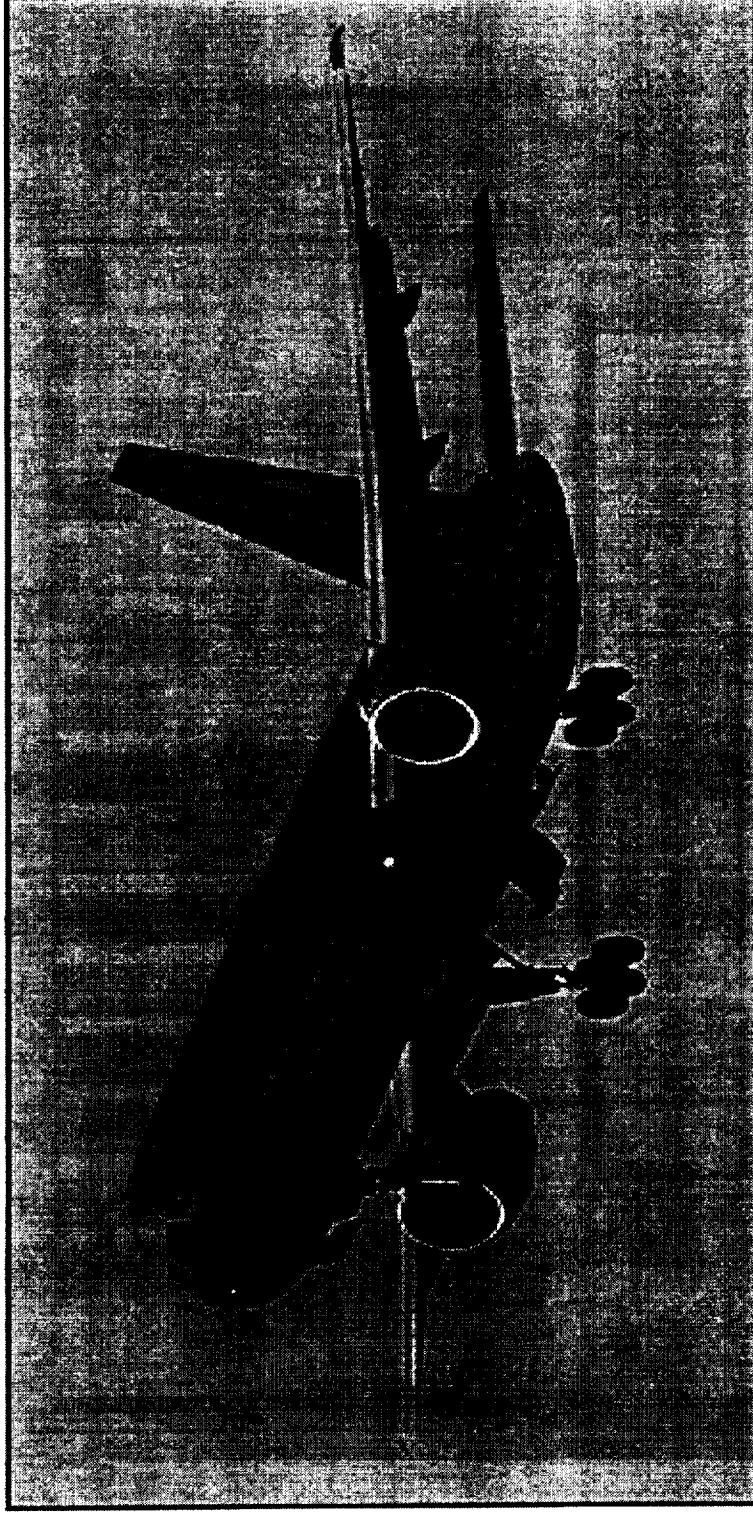


FIGURE 1.- PARALLEL RUNWAY OPERATIONS CONCEPT

Terminal Area Productivity

Advanced Subsonic Technology



**Robert Jacobsen
AST Level II Manager
Ames Research Center**

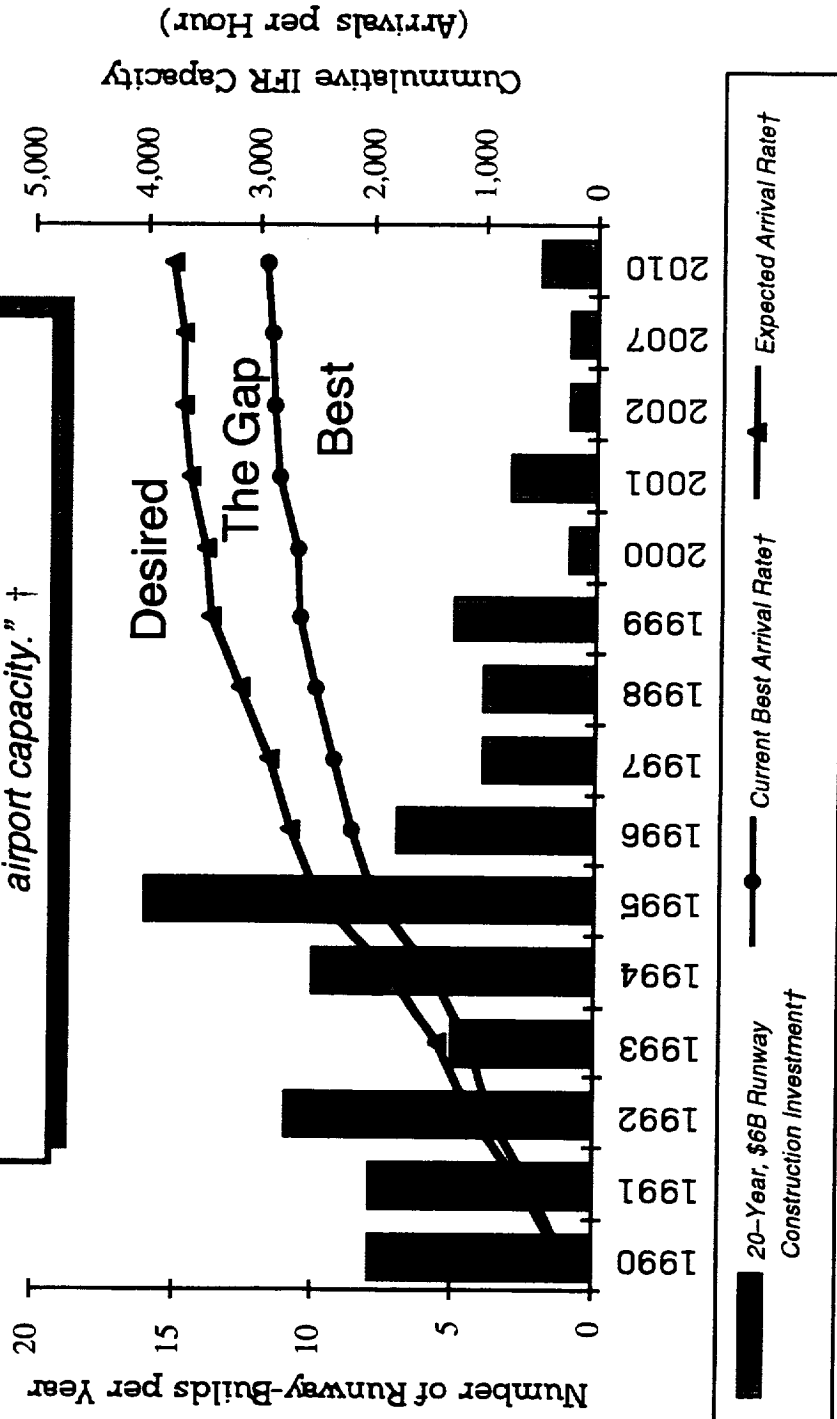
AST/Terminal Area Productivity

Terminal Area Productivity

Advanced Subsonic Technology

Challenge - The Capacity Gap

"Sixty-six of the top 100 airports have proposed new runways or runway extensions to increase airport capacity." †



† Reference: "1990-91 Aviation System Capacity Plan" DOT/FAA/SC-90-1, September 1990

Terminal Area Productivity

Advanced Subsonic Technology

**Achieve safe clear-weather airport capacity in
instrument-weather conditions**



Objectives:

With the U.S. airline and Aircraft Industries, the Airport Owners/Operators, and the FAA:

- Increase current non-visual operations for single runway throughput 12-15%
- Reduce lateral spacing below 3400 feet for independent operations on parallel runways
- Demonstrate equivalent instrument/clear weather runway occupancy time
- Meet FAA guidelines for safety

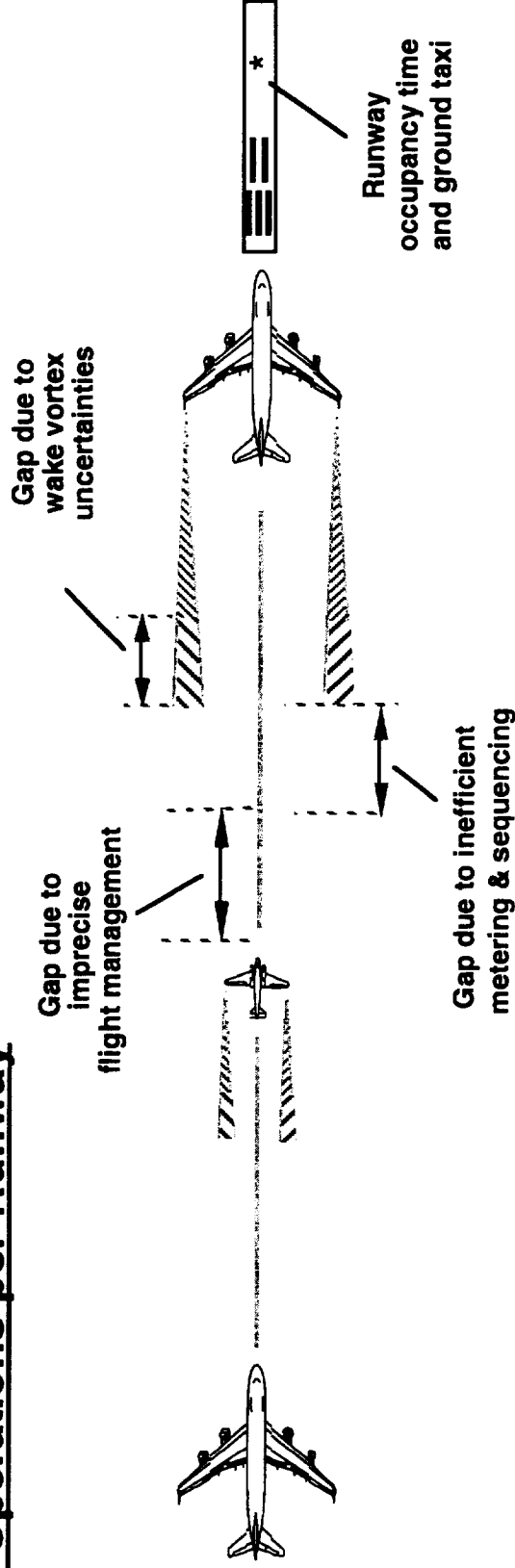
AST/Terminal Area Productivity

Terminal Area Productivity

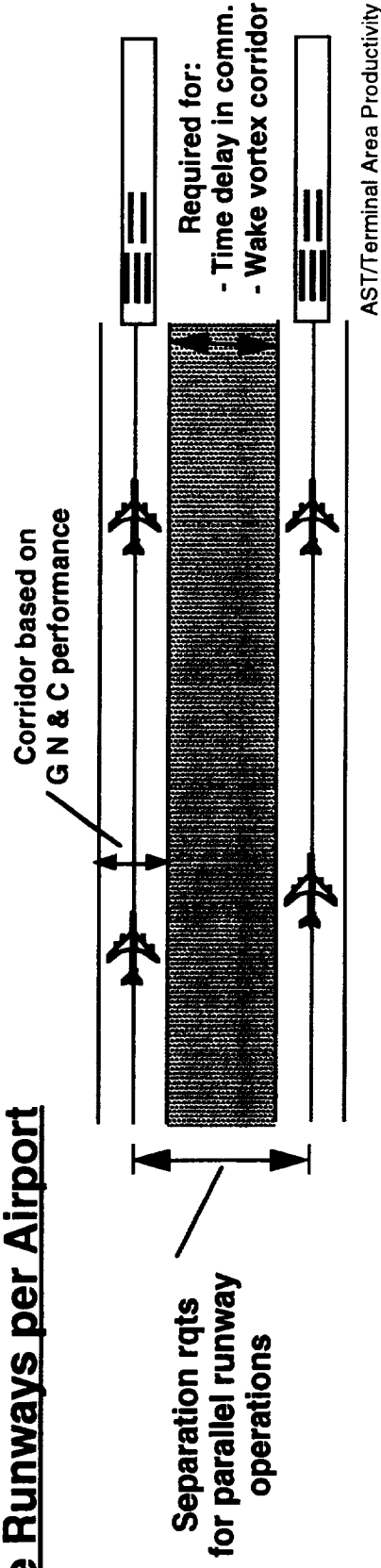
Advanced Subsonic Technology

Technical Approach

More Operations per Runway



More Runways per Airport

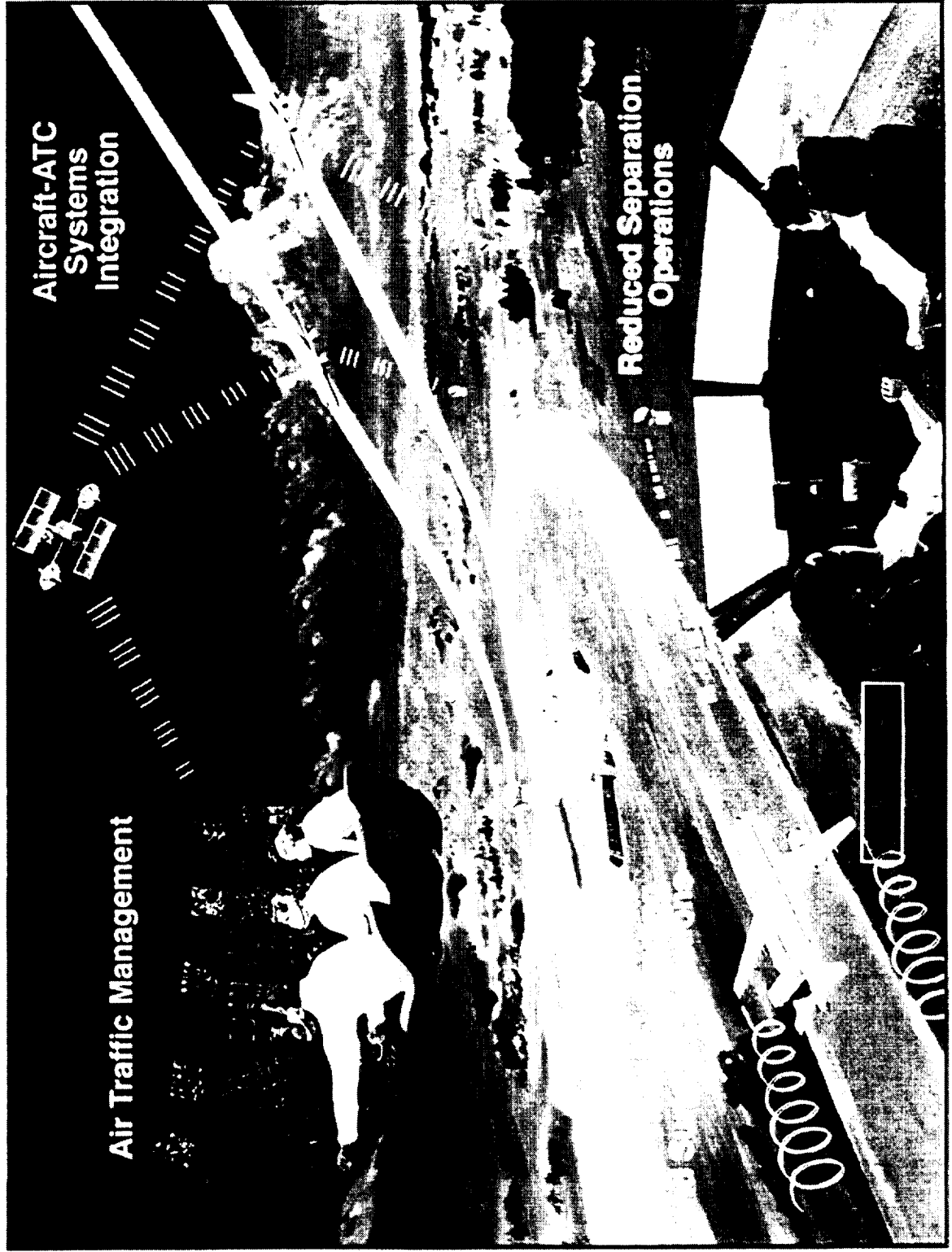


AST/Terminal Area Productivity

Terminal Area Productivity

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Program Elements



Terminal Area Productivity

Advanced Subsonic Technology

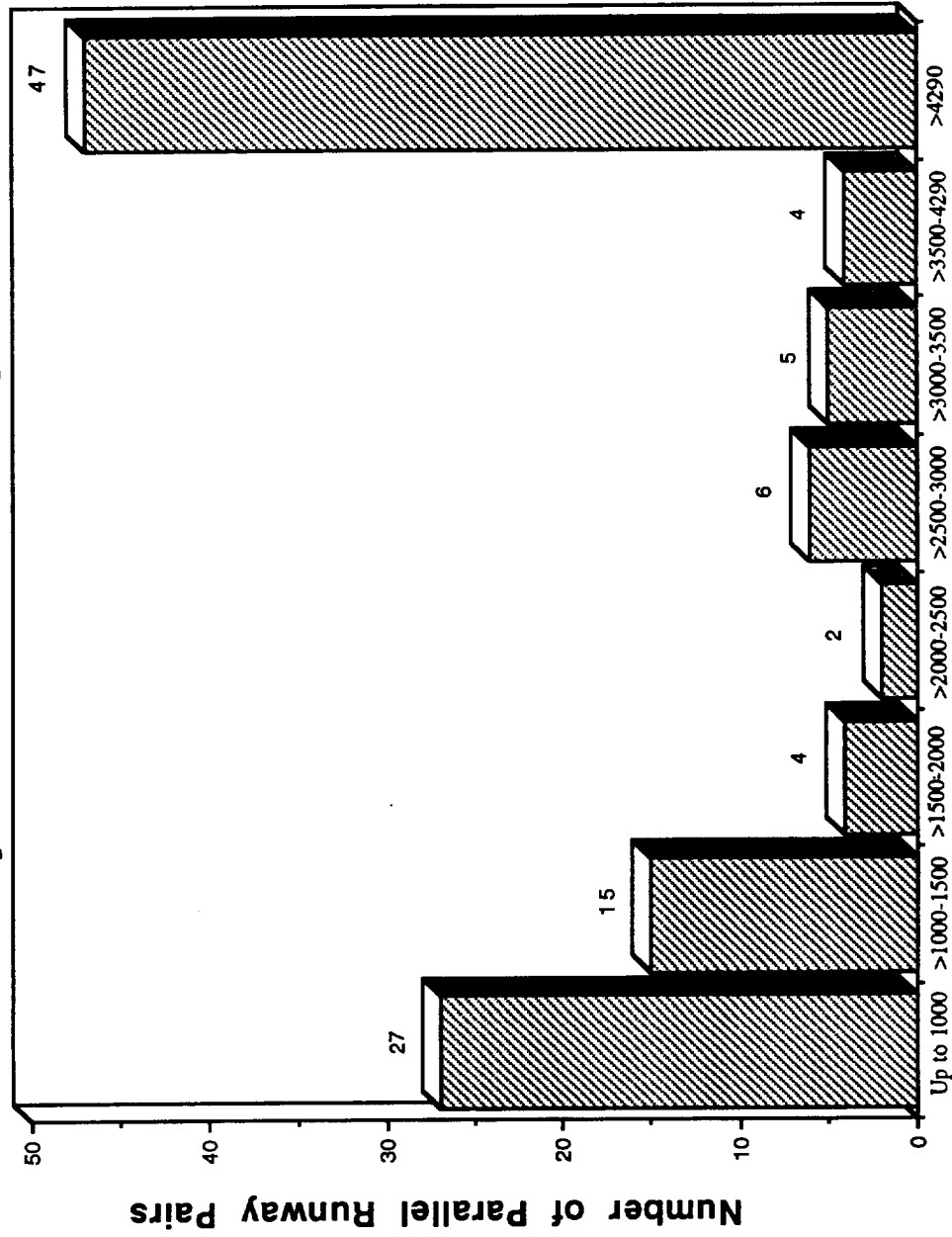
Program Deliverables

- **Systems for minimally constrained aircraft spacing**
 - Aircraft Vortex Spacing System (AVOSS)
 - Dynamic Spacing
 - Dynamic Routing
 - FMS/CTAS Integration
- **Blunder detection and guidance systems for reduced runway spacing**
 - Airborne Information for Lateral Spacing (AILS) system
- **Sensor/display/G & C technology to permit expeditious airport surface operations in Cat III conditions**
 - Dynamic Runway Occupancy Measurement (DROM) system
 - Roll Out and Turn Off (ROTO) system
 - Taxi Navigation and Situational Awareness (T-NASA) system
- **Integrated technology validation to accomplish clear-weather capacity in instrument-weather conditions**
 - Cost-benefit analyses
 - Procedure and Safety Substantiation (PSS)
 - Integrated technology demonstrations

Terminal Area Productivity

Advanced Subsonic Technology

Parallel Runway Pairs in the Top 100 U.S. Airports



Distance Between Runway Pairs, feet

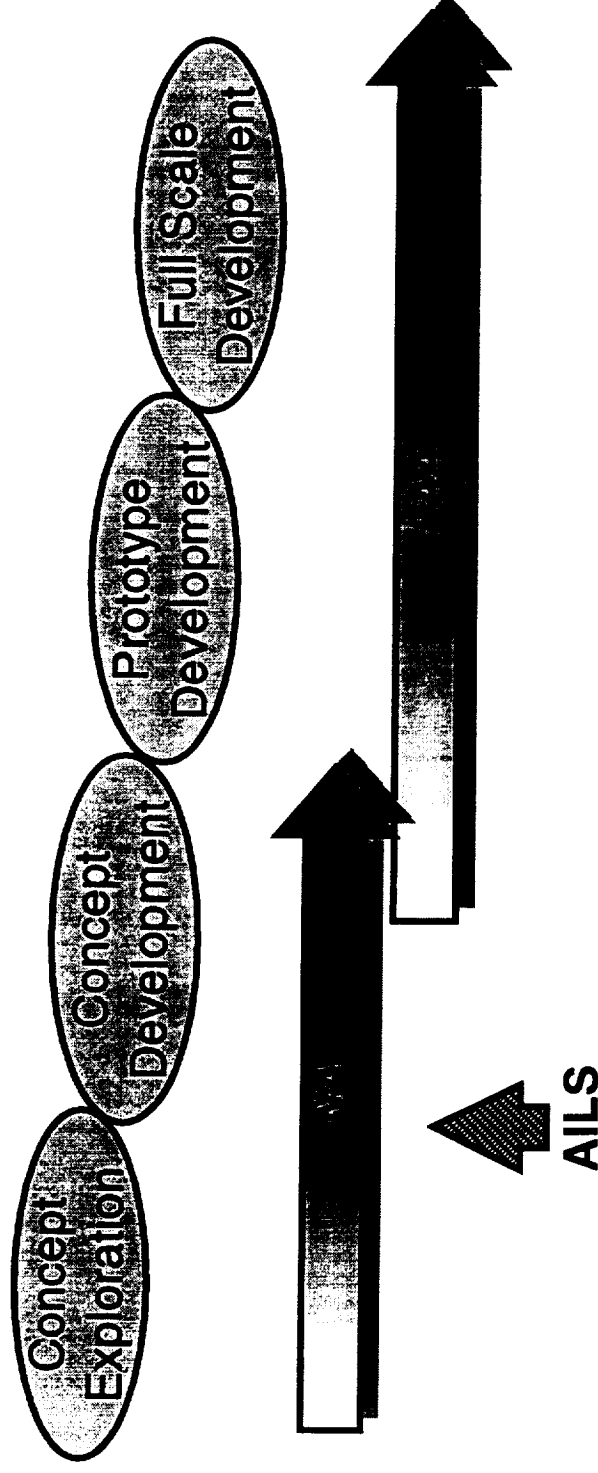
(Ref. 1995 Aviation Capacity Enhancement Plan; data from 67 of 71 airports with parallel runways.)

AST/Terminal Area Productivity

Terminal Area Productivity

Advanced Subsonic Technology

Airspace Technology Development Model



Risk Assessment

- Technological Risk - Low
- Implementation Risk - Depends on Industry Leadership
 - > Roles & Responsibilities
 - > Fleet Equipage

RSO and AILS Program Description and Overview

**Presentation to the
NASA Workshop on Flight-Deck-Centered
Parallel Runway Approaches in IMC
NASA Langley Research Center**

October 29, 1996

**R. Brad Perry
Manager, Reduced Spacing Operations
NASA Langley Research Center**



Reduced Spacing Operations

Terminal Area Productivity

Reduced Spacing Operations (RSO) Research Areas

- FMS/Center TRACON Automation System (CTAS)
 - NASA research to integrate FMS and CTAS capabilities
- Aircraft Vortex Spacing System (AVOSS)
 - NASA research to develop a dynamical aircraft wake vortex spacing capability for CTAS
- Airborne Information for Lateral Spacing (AILS)
 - NASA research to develop a flight deck-centered solution to IMC approaches to closely spaced parallel runways

Reduced Spacing Operations

Terminal Area Productivity

FMS/Center/TRACON Automation System (CTAS) Integration

- CTAS and FMS perform some similar functions
 - Calculate flight trajectories based on airplane performance
- CTAS and FMS have different objectives
 - FMS strives to minimize aircraft operating cost
 - CTAS strives to provide safe and efficient scheduling and separation of all aircraft
- Integration of FMS with CTAS has the potential to enhance both systems

Reduced Spacing Operations

Terminal Area Productivity

Aircraft Vortex Spacing System (AVOSS) Concept

- Separate aircraft from encounters with wake vortices of an operationally unacceptable strength
- Define protected corridor from outer marker to runway and predict time for vortex to clear corridor (“Transport Time”)
- Define operationally unacceptable wake strength and predict time to decay (“Decay Time”)
- Combine “Transport Time” and “Decay Time” into “Residence Time” and provide to ATC automation
- Monitor safety and provide predictor feedback with a wake vortex detection subsystem

Reduced Spacing Operations

Terminal Area Productivity

Airborne Information for Lateral Spacing

- AILS research goal of applying modern technology to develop procedures, tools, etc. to enable independent approaches to parallel runways with spacings less than the current 3400' Precision Runway Monitoring (PRM) spacing
- AILS research assumptions include:
 - Flight crews responsible for aircraft separation as with visual approaches
 - Information exchange between aircraft at least once per second (e.g., ADS-B)
 - Precise approach navigation (e.g., DGPS)
 - Worst case intrusion scenario of a 30 degree intercept
 - Alerting algorithms and timely evasive maneuvering to avoid intruder aircraft

Reduced Spacing Operations

Terminal Area Productivity

Industry/User Interest in AILS

- Seattle-Tacoma International capacity enhancement planning for a new parallel runway at 2500' or 1800' lateral spacing
- Boston Logan International loss of capacity in IMC with existing parallel runway lateral spacing
- Two major avionics companies have identified significant technical feasibility and market potential
- United Airlines interest in improving IMC capacity at San Francisco International
- Ongoing interaction and support from FAA/Precision Runway Monitoring (PRM) Program

Reduced Spacing Operations

Terminal Area Productivity

ALLS Simulation Studies Overview

- Three NASA simulation studies to date (Two Langley and one Ames)
- Two different simulation fidelities used
 - Langley studies used the Transport System Research Vehicle (TSRV) simulator
 - Ames used desk-top simulator
- Different cockpit displays (PFD and ND) used by Langley and Ames
- Aircraft control mode varied
 - Langley studies manual (hand flown)
 - Ames study auto-coupled

Reduced Spacing Operations

Terminal Area Productivity

AIS Simulation Studies Overview (continued)

- Approach navigation varied
 - Langley used DGPS
 - Ames used ILS
- Different alerting algorithms used in each study
- Different alerting displays used in each study
- Evasive guidance commands varied
 - Two studies used evasive guidance (different versions)
 - One study used none

Reduced Spacing Operations

Terminal Area Productivity

ALLS Simulation Studies Overview (continued)

- Evasive maneuvering in all three studies was manually flown
 - Langley used a trained, consistent evasive maneuver
 - Ames evasive maneuver varied with encounter configuration
- Test subject utilization varied
 - Two studies used single test subjects as the pilot flying
 - One study used a two member test subject crew
- All three studies used current EFIS-qualified airline pilots as test subjects

Reduced Spacing Operations

Terminal Area Productivity

Upcoming AILS Simulation Study and Flight Demonstration Schedule

- Follow-on simulation experiment(s) as applicable
- Nov 1996: Integrated required navigation performance test using single NASA aircraft
- Nov 1998: Conflict detection and resolution test using two NASA aircraft
- 1999: Integrated AILS Terminal Area Productivity (TAP) flight demonstration (Two Aircraft)

Reduced Spacing Operations

Terminal Area Productivity

Some Major Issues to Resolve in Implementing AILS Operationally

- Datalink (e.g., ADS-B) availability
- Enhanced aircraft navigation availability (e.g., DGPS)
- Airline fleet equipage
- Airborne/ground roles and responsibilities
- AILS certification and operational readiness
- Others??

FLIGHT DECK CENTERED CLOSE PARALLEL RUNWAY APPROACHES: 3400 and 2500 FT

**Marvin Waller and Charles Scanlon
October 1996**

AILS CONCEPT TEAM

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Brad Perry	NASA LaRC
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Terry Abbott	NASA LARC
Trent Thrush	NASA ARC
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Gary Lohr	JIL Corp.
Steve Koczo	Rockwell-Collins
Scott Chamberlin	Rockwell-Collins
James Kuchar, Ph.D.	MIT
Brenda Carpenter	MIT
Amy Pritchett	MIT

OUTLINE

APPROACH

ASSUMPTIONS

CONCEPT

EXPERIMENT OBJECTIVES

EXPERIMENT DESIGN

RESULTS

CONCLUSIONS

APPROACH

(3400 and 2500 FT RWY SPACING STUDY)

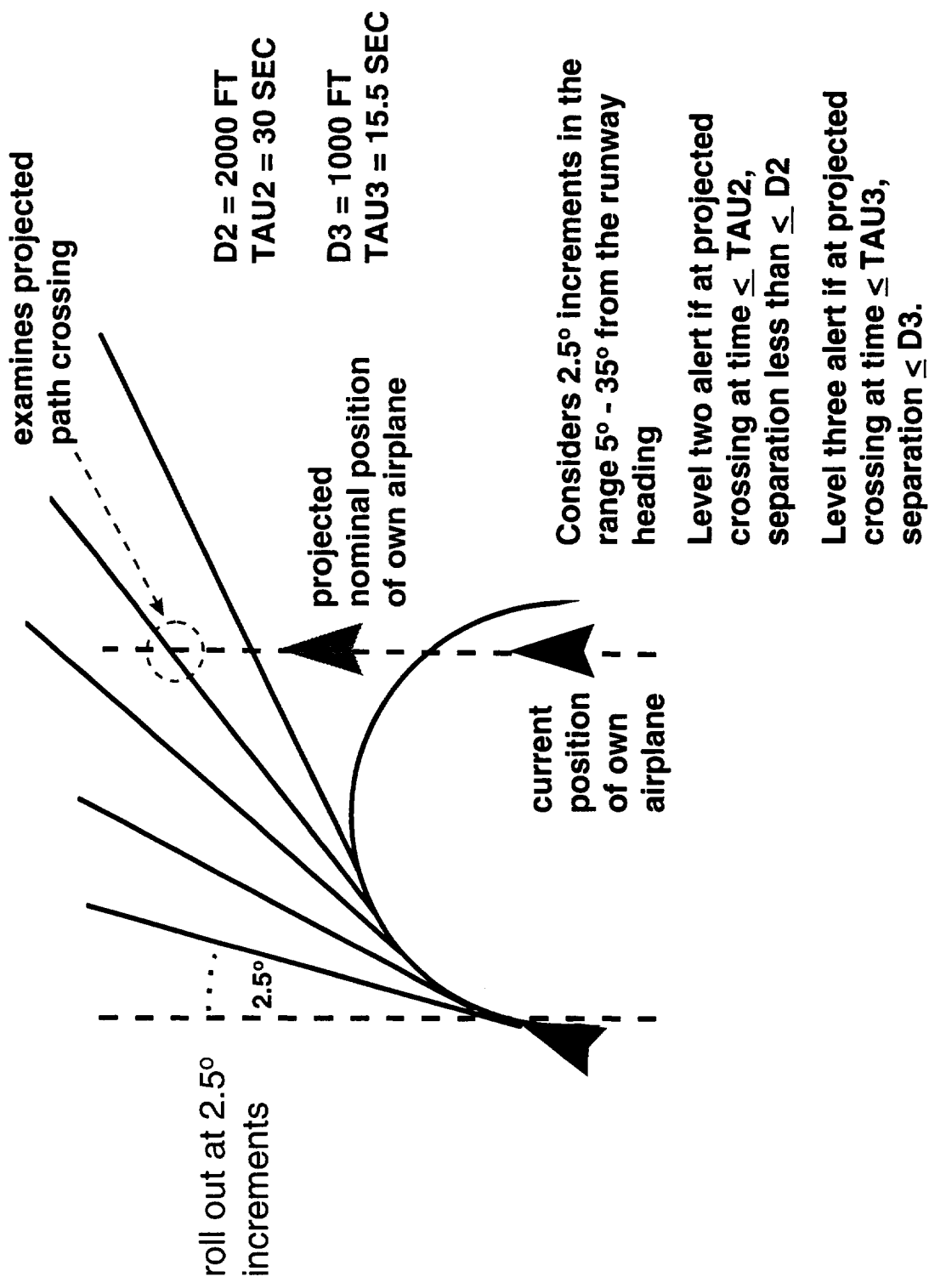
- **LaRC TEAM DESIGNED INITIAL CONCEPT FOR CLOSELY SPACED PARALLEL APPROACHES USING FLIGHT DECK CENTERED TECHNOLOGY**
- **TEST THE DESIGN IN A STUDY IN THE TSRV FIXED BASED FACILITY**
- **COMPARE PERFORMANCE WITH TWO FLIGHT DECK DISPLAY PRESENTATIONS**
 - **MINIMAL MODIFICATIONS TO CURRENT GLASS FLIGHT DECKS, 10 NM DISPLAY RANGE IN ND**
 - **DESIGN TEAM CONFIGURATION, 2 NM DISPLAY RANGE**

ASSUMPTIONS

- RESPONSIBILITY FOR SEPARATION WILL BE HANDED OFF TO THE FLIGHT DECK AS IN VMC
- ATC WILL BE AVAILABLE TO ASSUME CONTROL AFTER RESOLUTION OF AN INTRUSION
- ACCURATE SENSING TECHNOLOGY WILL PROVIDE NEEDED MEASUREMENTS FOR NAVIGATION AND DISPLAYS
- NON-AUTOPILOT MODE (ATTITUDE CONTROL WHEEL STEERING)
- 1000 FT. VERTICAL SEPARATION ON INTERCEPTING THE LOCALIZER
- GLASS FLIGHT DECK (SOFTWARE MODIFICATIONS)
- ON BOARD ALERTING ALGORITHMS OPERATIONAL

SEGMENTED ALERTING CRITERION

(BASED ON ROCKWELL-COLLINS CONTRACTED DEVELOPMENT)



CONCEPT DESIGN

**APPLY FLIGHT DECK CENTERED TECHNOLOGY TO ASSIST THE
FLIGHT CREW IN**

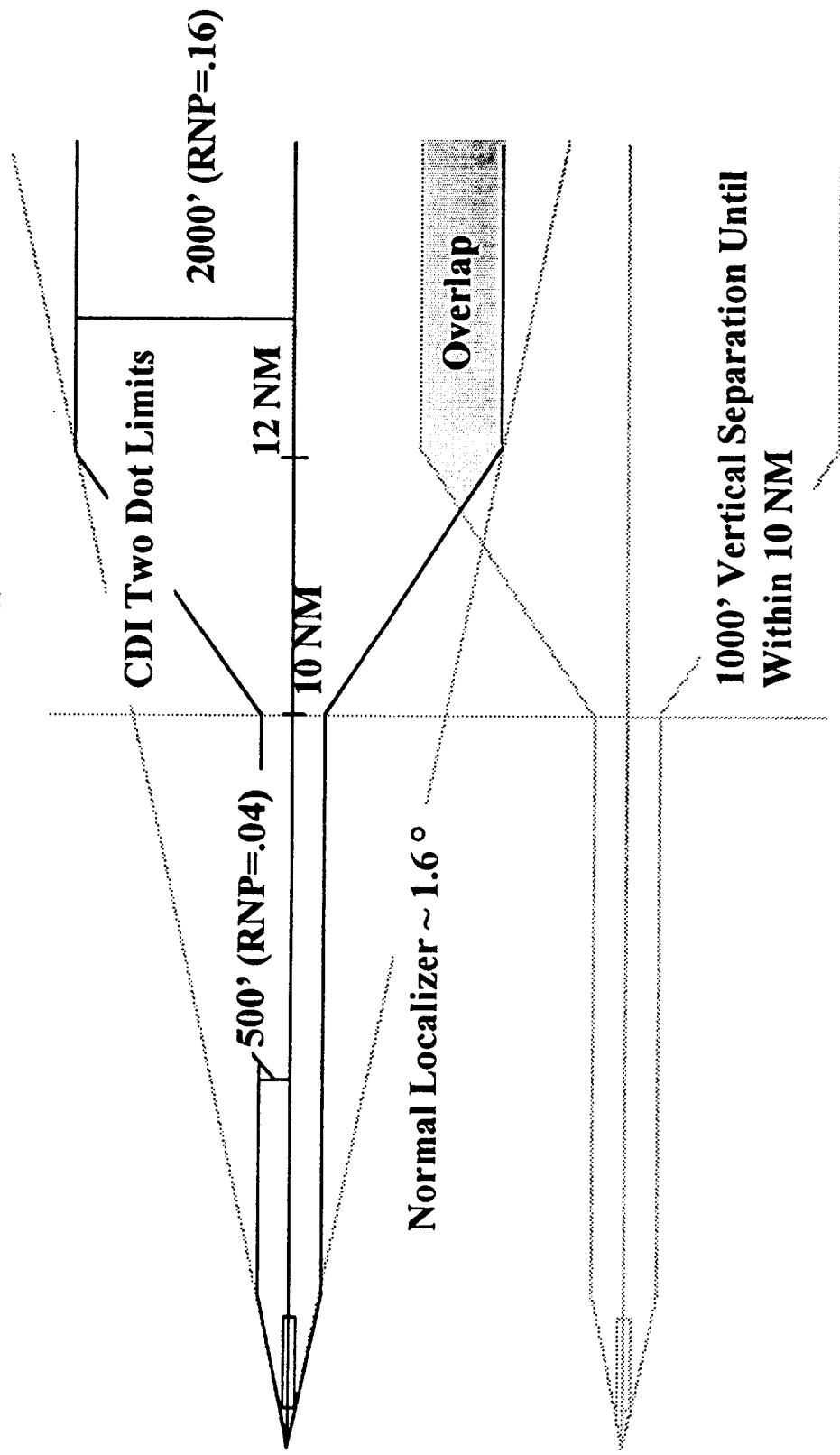
- **ACCURATE NAVIGATION DURING CLOSELY SPACED
PARALLEL APPROACHES**
- **AVOIDING CLOSER THAN 500 FT. ENCOUNTERS IN THE
EVENT OF AN INTRUSION INCIDENT**

FLIGHT DECK PROCEDURES TO ASSIST PILOTS IN ACCURATE NAVIGATION

- PILOT FLYING CAPTURES THE LOCALIZER AND GLIDESLOPE AND MAINTAINS THE FLIGHT WITHIN ONE DOT OF LOCALIZER DEVIATION**
- ONE DOT LOCALIZER DEVIATION TRIGGERS AN ALERT WITH AMBER DISPLAY COLOR CHANGES (LEVEL TWO)**
- TWO DOTS LOCALIZER DEVIATION TRIGGERS AN ALERT WITH RED DISPLAY COLORS, AURALS AND REQUIREMENT TO EXECUTE AN EMERGENCY TURN AND CLIMB PROCEDURE (LEVEL THREE)**

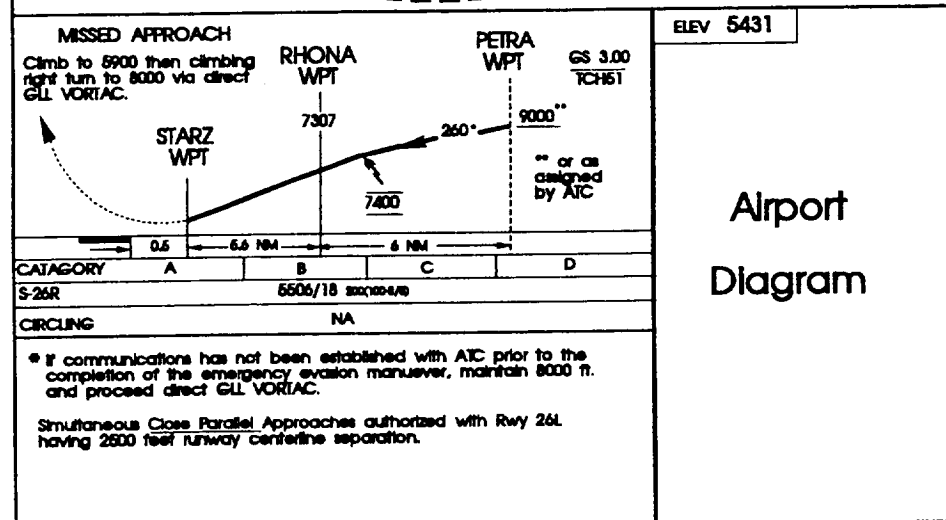
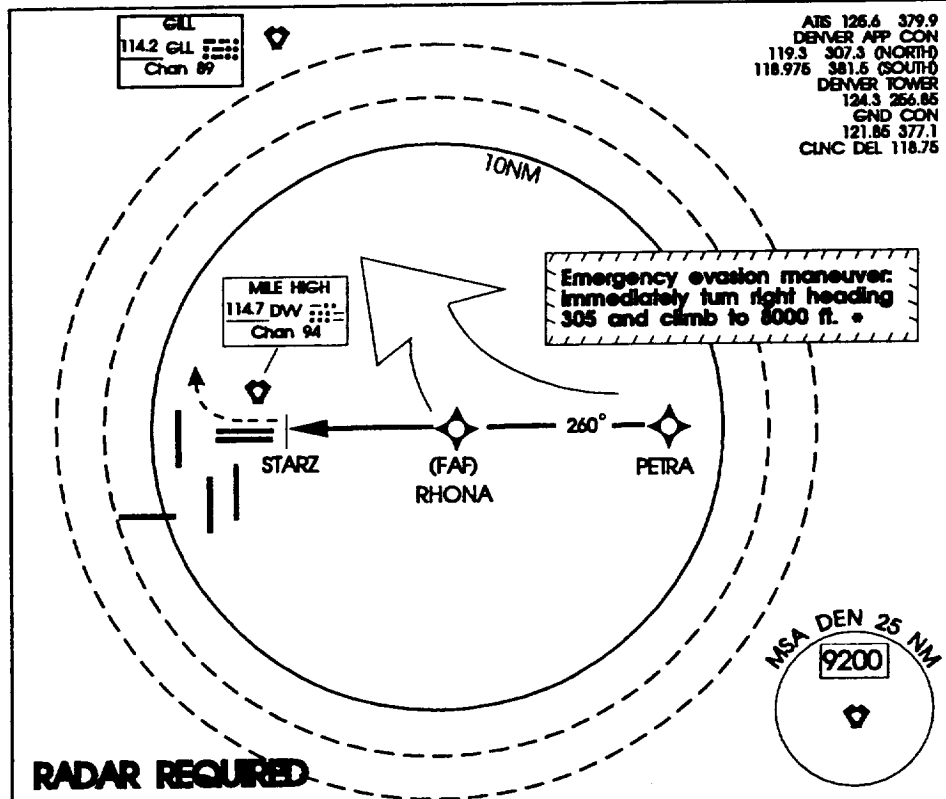
Required Navigation

“Rocket Ship”



CSP RWY 26R

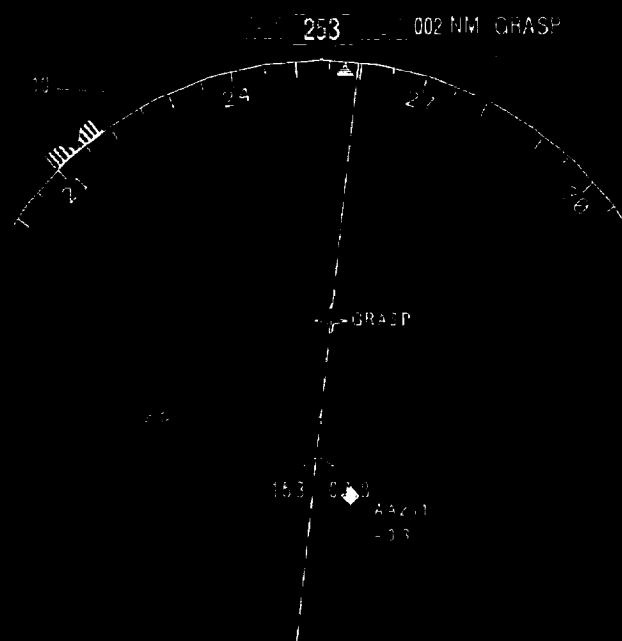
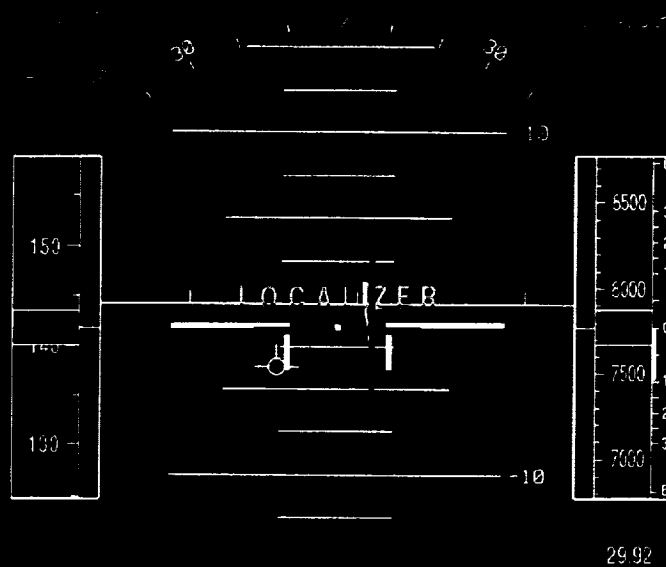
DENVER INTL (DEN)
DENVER, COLORADO



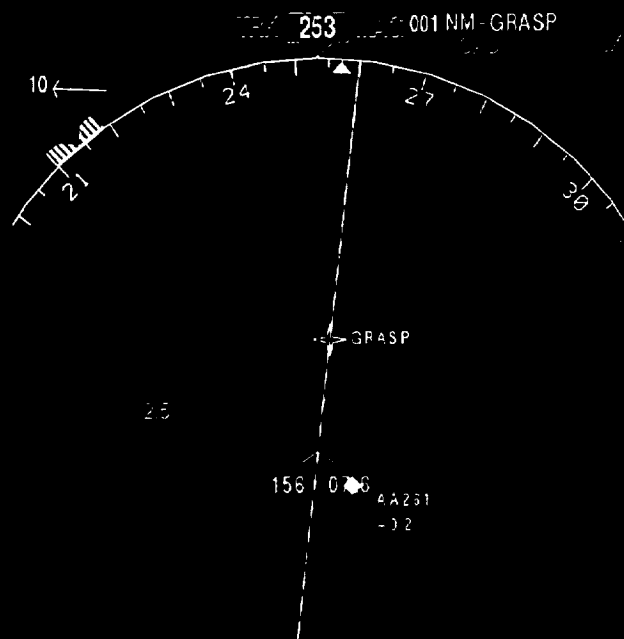
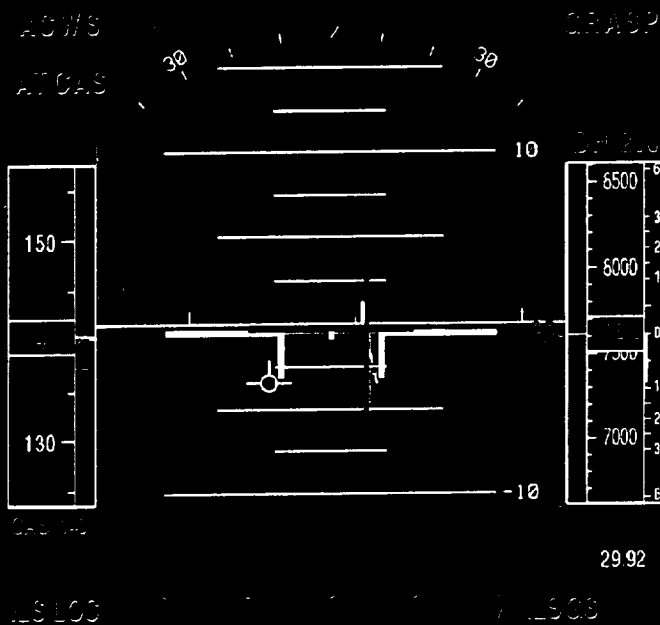
CSP RWY 26R

DENVER INTL (DEN)
DENVER, COLORADO

10 NM RANGE, LOCALIZER ALERT



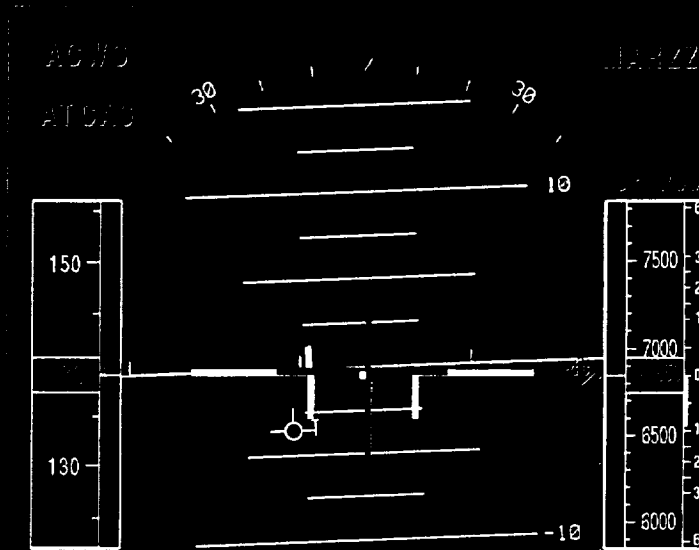
10 NM RANGE, TWO DOT AT RT



FLIGHT DECK PROCEDURES IN THE EVENT OF AN INTRUDER ALERT

- EXECUTE AN IMMEDIATE CLIMBING, ACCELERATING TURN AWAY FROM THE TRAFFIC TO A HEADING 45 DEGREES FROM THE RUNWAY HEADING (AS PUBLISHED ON THE APPROACH PLATE), LEVEL THREE ALERT**
- CONTACT ATC AS USUAL ON DEVIATING FROM CLEARANCE**

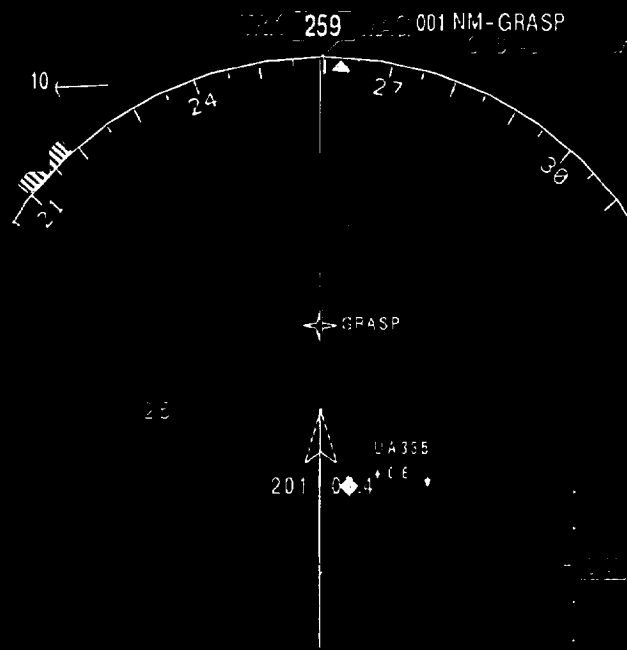
10 NM RANGE, NO ALERTS



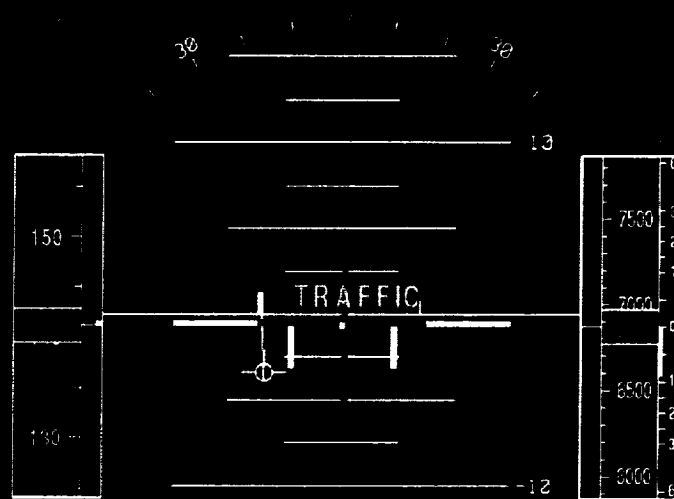
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10100

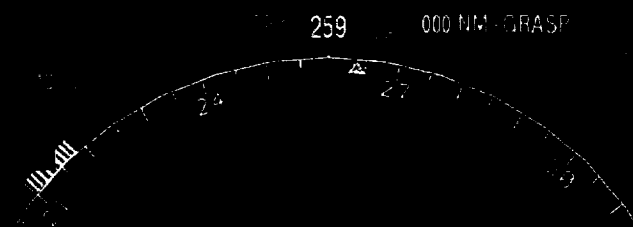
10100



10 NM RANGE, TRAFFIC ALERT

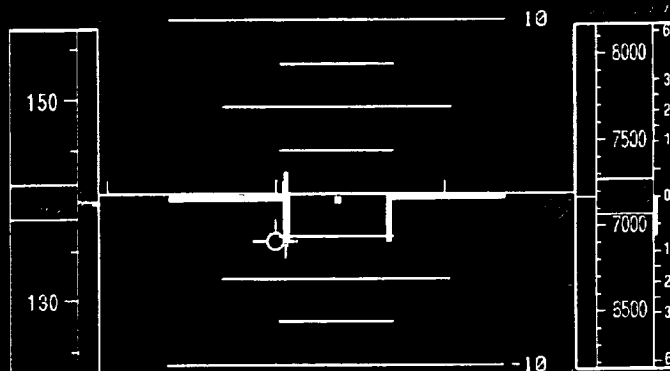


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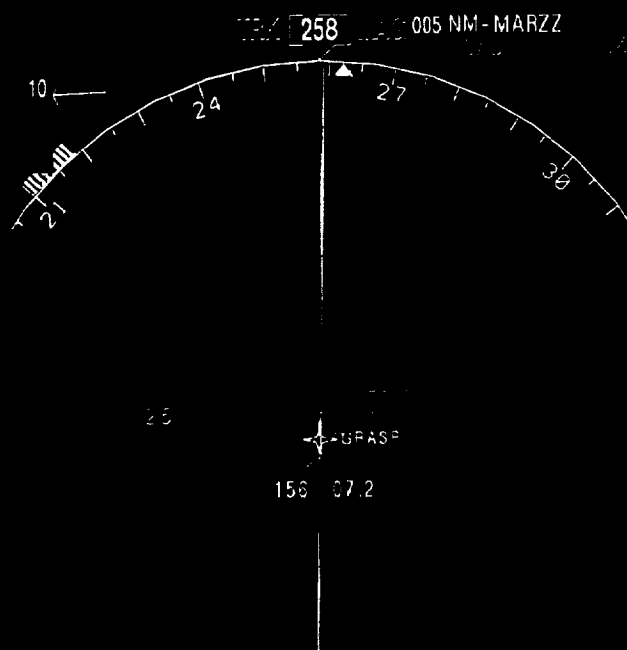
10 NM RANGE, W/ FINE ALERT

AC 76 22
AT 043 30 30



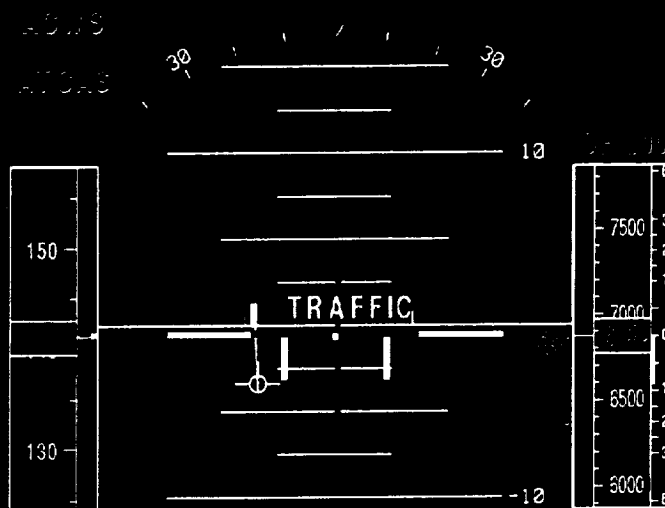
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18100 18100





2 NM RANGE, TRAFFIC ALERT



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EXPERIMENT OBJECTIVE

EVALUATE, IN SIMULATION, AN EXPERIMENTAL CONCEPT FOR CONDUCTING PARALLEL RUNWAY OPERATIONS IN IMC. THE CONCEPT INCLUDES

- INFORMATION PROCESSING**
- DISPLAYS**
- PROCEDURES**

TEST MATRIX

- **RUNWAY SPACINGS**
 - 3400 FT.
 - 2500 FT.
- **TWO DISPLAY LEVELS**
 - MODIFIED CONVENTIONAL (10 NM RANGE)
 - DESIGN TEAM ENHANCED (2 NM RANGE)
- **TWO INTRUDER SPEEDS**
 - INTRUDER 30 KNOT FASTER
 - INTRUDER 30 KNOTS SLOWER
- **SEVEN SCENARIOS**
 - FIVE WITH 30° HEADING DEVIATION
 - ONE NORMAL
 - ONE WITH PARALLEL TRAFFIC BREAKOFF

TEST VARIABLES

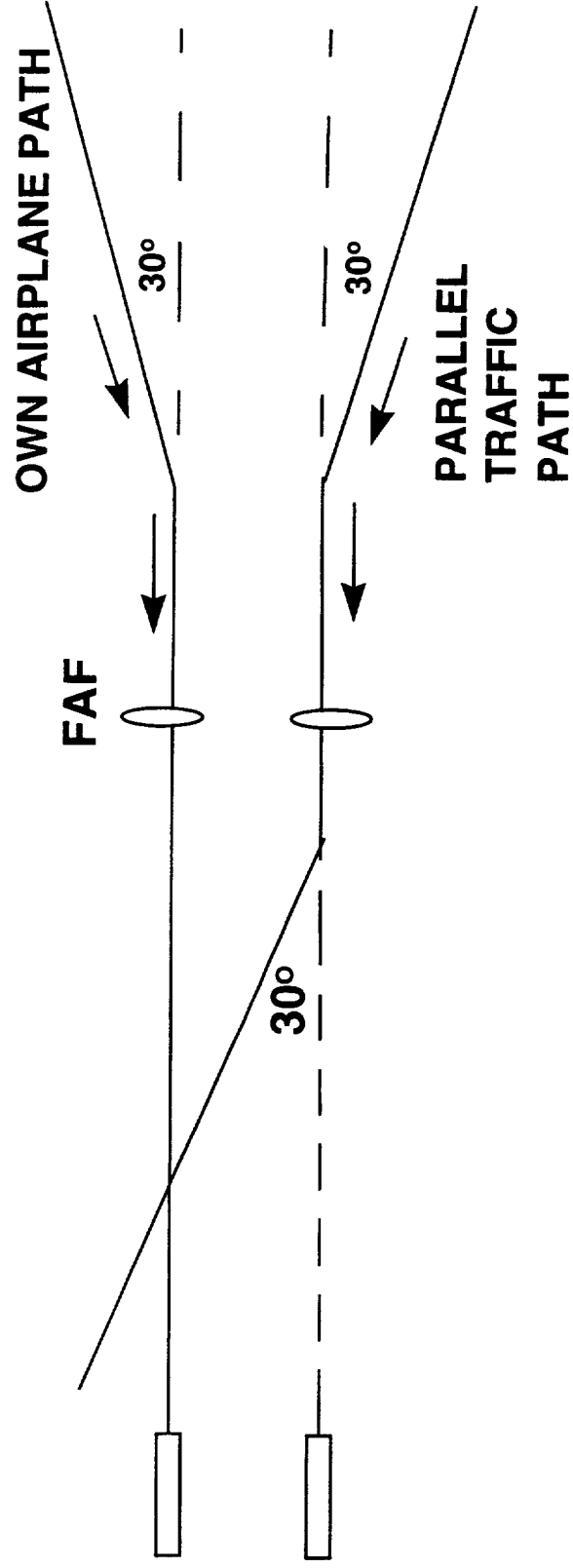
- **INDEPENDENT VARIABLES**
 - **DISPLAYS** 2 LEVELS
 - **RUNWAY SPACINGS** 2 LEVELS
 - **RELATIVE SPEED OF AIRCRAFT** 2 LEVELS
 - **SCENARIOS** 7 LEVELS

16 LINE AND MANAGEMENT PILOTS

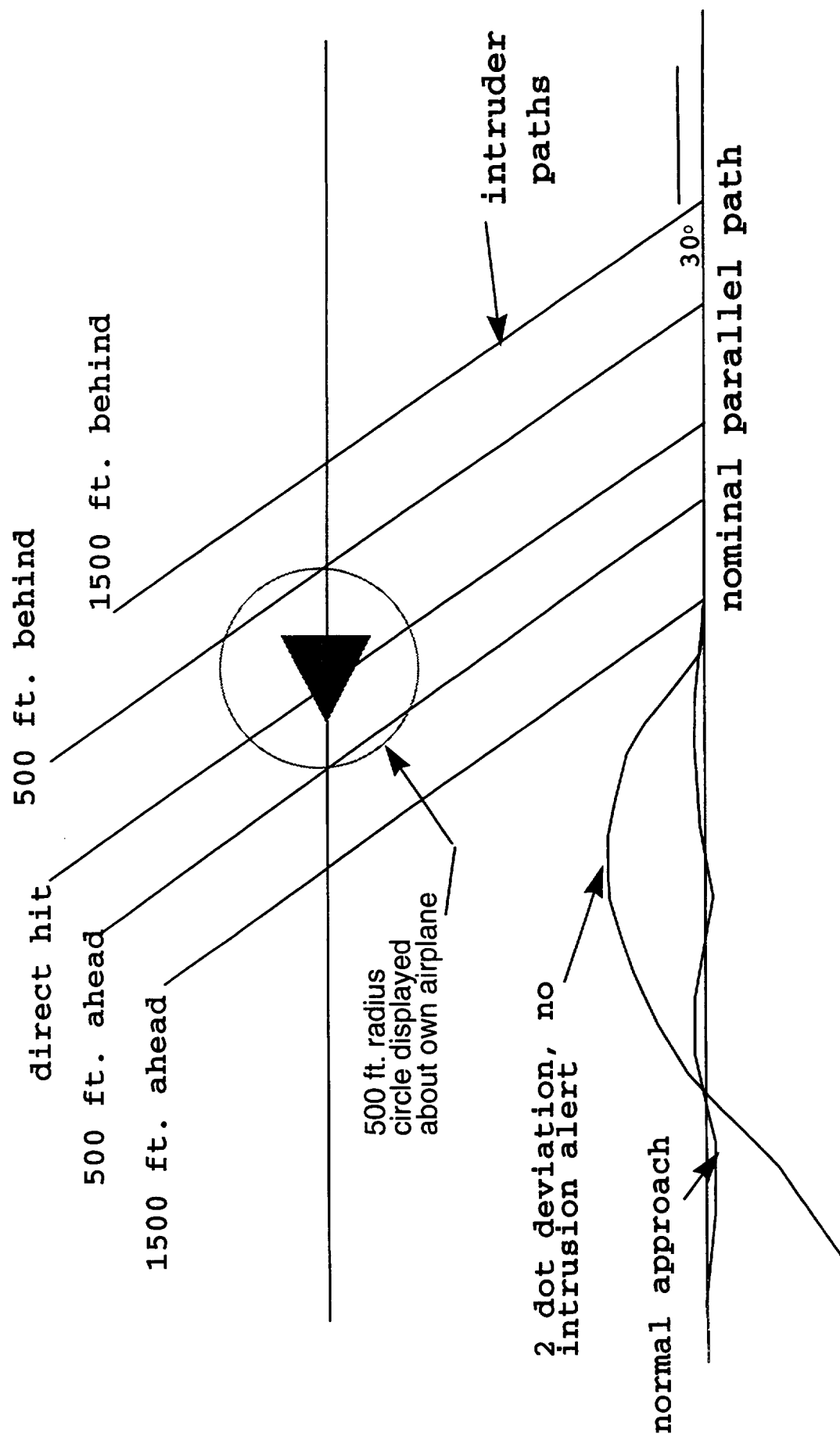
(56 RUNS / PILOT, IN 2 TEST DAYS, 6 RUNS /HR.)

- **DEPENDENT VARIABLES**
 - **PILOT REACTION TIME**
 - **CLOSEST APPROACH DISTANCE**
 - **PILOTS EVALUATIONS**
 - **PILOT SCANNING BEHAVIOR**

INTRUSION SCENARIO FORMAT

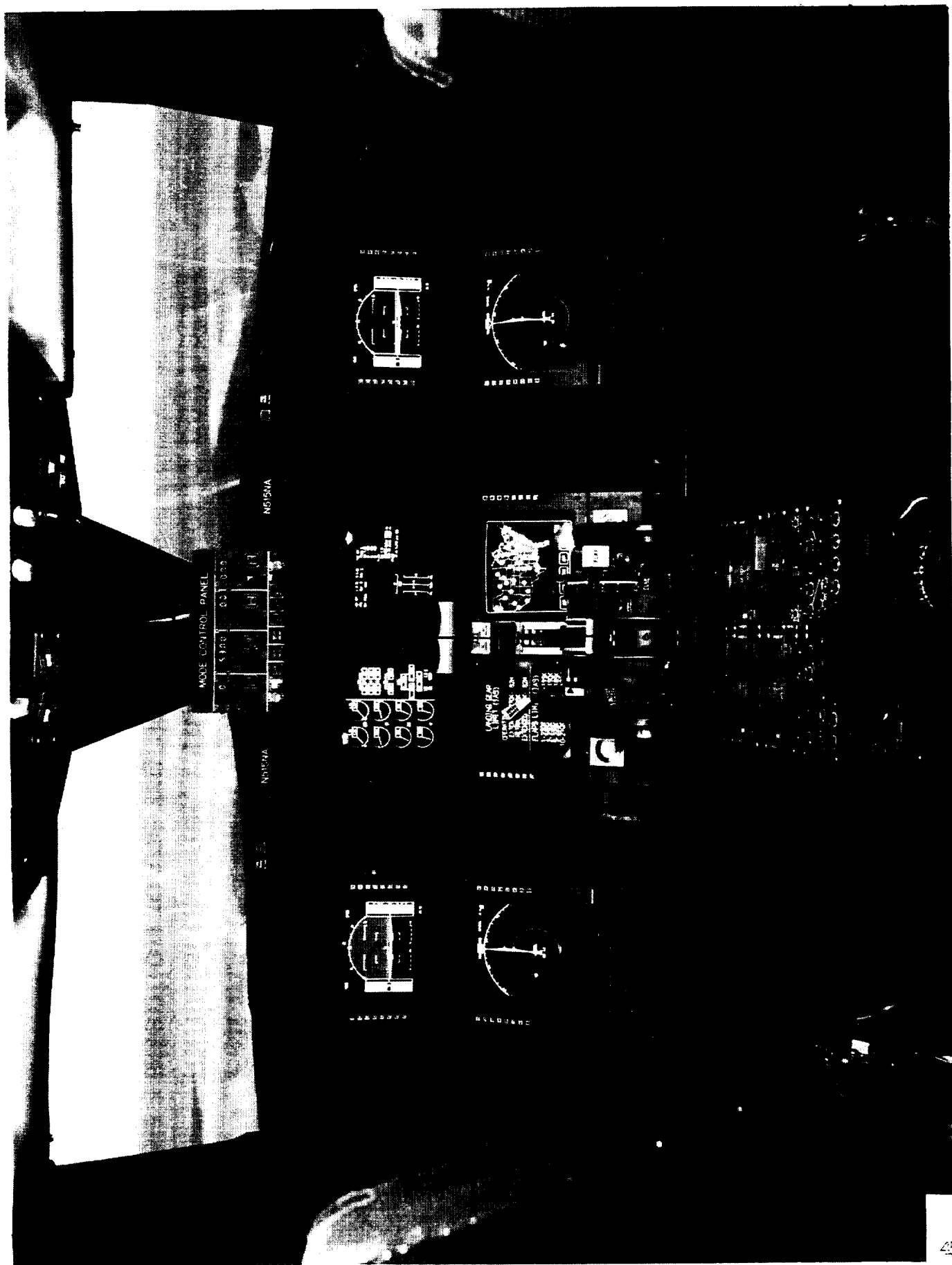


SEVEN SCENARIOS



SIMULATED AIRSPACE

- **DENVER INTERNATIONAL AIRPORT (DIA)**
- **CHANGE EXISTING RUNWAY 26 TO 26L, ADD RUNWAY 26R AT TWO DIFFERENT SPACINGS, WITH IDENTICAL DIMENSIONS, EVEN THRESHOLDS (NOT STAGGERED)**
- **LOCALIZER INTERCEPT ALTITUDES SEPARATED BY 1000 FT. AT 7400 AND 8400 FT**



PILOTS' EVALUATION

- **This is definitely a realistic process and an excellent start**
- **The pilots generally preferred the 2 NM display capability**
- **They felt that the task can be accomplished adequately with the 10 NM map scale**
- **Recommended that the escape heading be displayed in the PFD**
- **Recommended providing escape guidance in the PFD. Most recommended using the FD command bars**
- **Felt that the pilot flying would use the ND display in a minimal manner, while a PNF would pay heavy attention to the traffic display**

PILOT REACTION TIME

(From level three alert until 50% lateral side stick deflection)

1.5

1.25

1

Time (sec.)

0.75

0.5

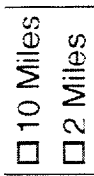
0.25

0

Average

2500 ft.

3400 ft.

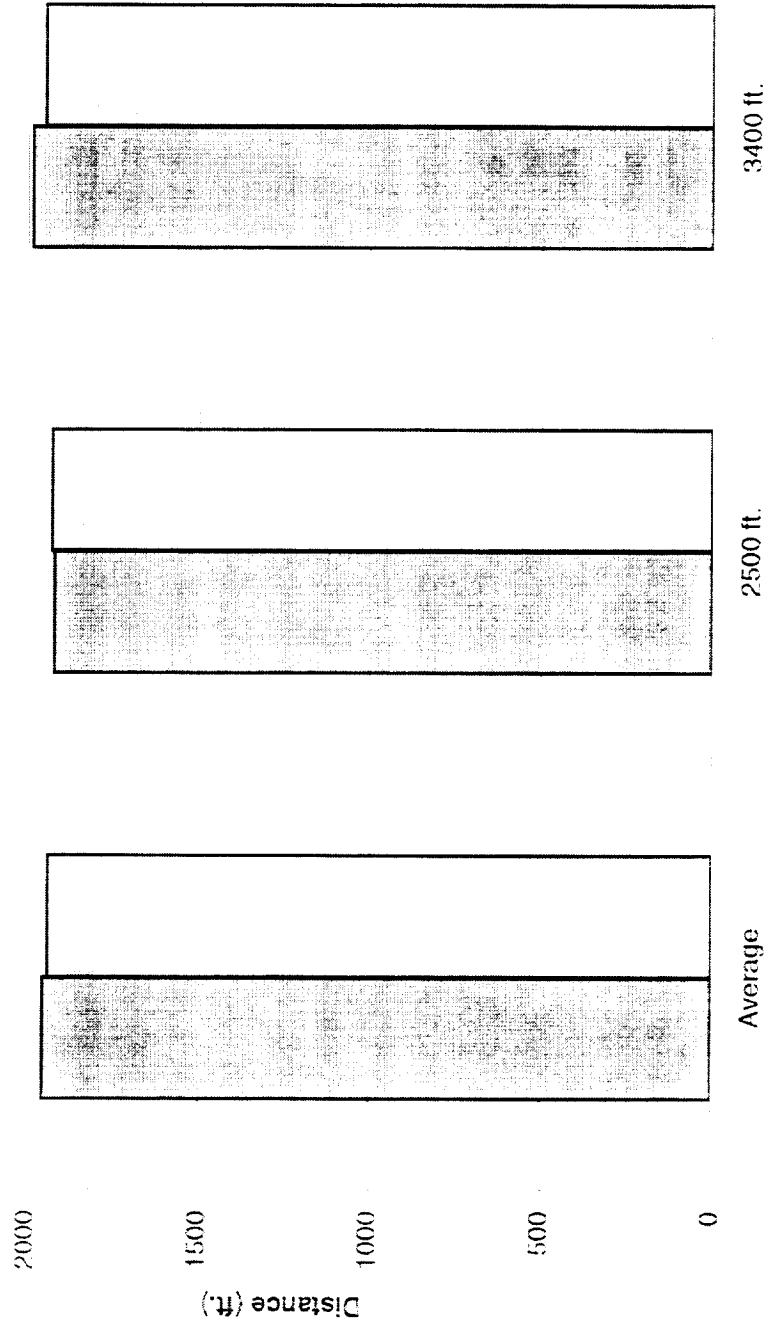


Runway Separations

	Count	Mean	Std	Max	Min
10 Miles					
Average	192	0.70	0.19	1.31	0.03
2500 ft.	96	0.71	0.19	1.28	0.19
3400 ft.	96	0.69	0.20	1.31	0.03
2 Miles					
Average	192	0.73	0.25	1.78	0.03
2500 ft.	96	0.73	0.22	1.44	0.41
3400 ft.	96	0.72	0.28	1.78	0.03

Minimum Separation From Time of Alert to End

	Count	Mean	Std	Max	Min
10 Miles					
Average	192	1953	274	2395	1183
2500 ft.	96	1921	293	2395	1183
3400 ft.	96	1986	251	2355	1319
2 Miles					
Average	192	1939	258	2437	1242
2500 ft.	96	1927	268	2437	1242
3400 ft.	96	1950	248	2298	1276

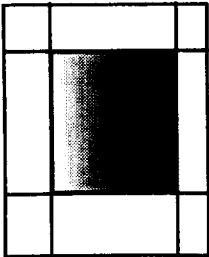


Runway Separations

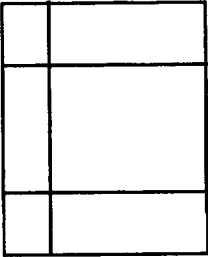
LOOK POINT DATA

CENTER OF PFD
(ATTITUDE/COMMAND BARS)

WINDOW



PFD



ND

	DWLSEC	DWLPCT	NO-FIX.	PCT-FIX	DUR-FIX
MEAN 10 NM	224.48	11.13	64.56	8.63	12.82
MEAN 2 NM	218.96	10.44	71.63	7.66	10.96
t-VALUE (2 TAIL)	0.77	-1.45	-2.84	2.37	3.04
SIGNIFICANCE	0.437	0.147	.005	.018	.003

CONCLUSIONS

- **THE CONCEPT APPEARS TO BE PROMISING FOR APPROACHES TO RUNWAYS SEPARATED 3400 FT AND 2500 FT.**
- **PILOT REACTION TIME WAS LESS THAN THE TARGETED 2 SECOND MAXIMUM VALUE.**
- **THE MEAN VALUE OF THE CLOSEST APPROACH WAS APPROXIMATELY 1950 FT. WITH A SD OF 270 FT.**
- **THE CLOSEST APPROACH FOR ALL RUNS WAS 1183 FEET.**
- **THE PILOTS LIKED THE PROCESS AND OFFERED NO RESERVATIONS ABOUT FLYING IT.**
- **SOME RECOMMENDATIONS FOR DISPLAY MODIFICATIONS WERE MADE.**



Airborne Information for Lateral Spacing: NASA Flight-Deck- Centered Workshop Review

Trent Thrush

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TT-10/29/96 Pg 01



Overview

- Objectives
- Previous Research
- Assumptions
- Approach
- Measures
- Results
- Conclusions



Objectives

- Investigate airborne alerting/collision-avoidance systems (CAS) that could enable pilots to conduct simultaneous approaches to closely-spaced (< 3400 ft) parallel runways in Instrument Meteorological Conditions (IMC)
- Investigate the performance differences between a current airborne alerting/CAS based on 2D (vertical) guidance for conflict resolution against an alternative alerting system utilizing 3D (vertical & lateral) guidance
- Investigate whether additional display information and extensions are beneficial in enabling pilots to conduct simultaneous approaches to closely-spaced parallel runways
- Investigate whether pilots prefer additional display information and extensions to current displays



Previous Research

- Traffic alerts and guidance commands are required for conflict resolution. Without alerts and collision avoidance commands, pilots had significantly more incidents with low aircraft separation and executed significantly more unnecessary avoidance maneuvers.
- The collision avoidance commands were not always followed. Guidance commands were satisfied in only about 60% of the maneuvers flown by the pilots.
- More informative displays of the intruders current state did not always produce better aircraft separation. This may be related to pilot's lower rate of conformance to the automatic commands with the displays, which in turn was correlated with lower performance.

- *Amy Pritchett, MIT Aero Systems Lab, P-Rwy Ops Studies*



Assumptions

- Navigation Improvements: Current ILS augmented with ADS-B. Heading, ground speed, bank angle, and accurate position data exchanged between aircraft.
- Standard Alerting Levels and Traffic Symbolology:
 - *Stage-1*: Amber-caution / Traffic Alert (TA)
 - *Stage-2*: Red-warning / Resolution Advisory (RA)Standard traffic symbology: Other-traffic, proximate-traffic, TA-traffic, and RA-traffic on ND-Map.
- Auto-coupled Approach Procedure: Auto-flight (AF) system/standard modes, dual-cue flight-director active.
- Worst-Case Blunder Scenario: Single encounter resulting in a 30° interception. Multiple aircraft not presented.
- Conflict Resolution Commands Provided: RA Guidance.



Assumptions (cont'd)

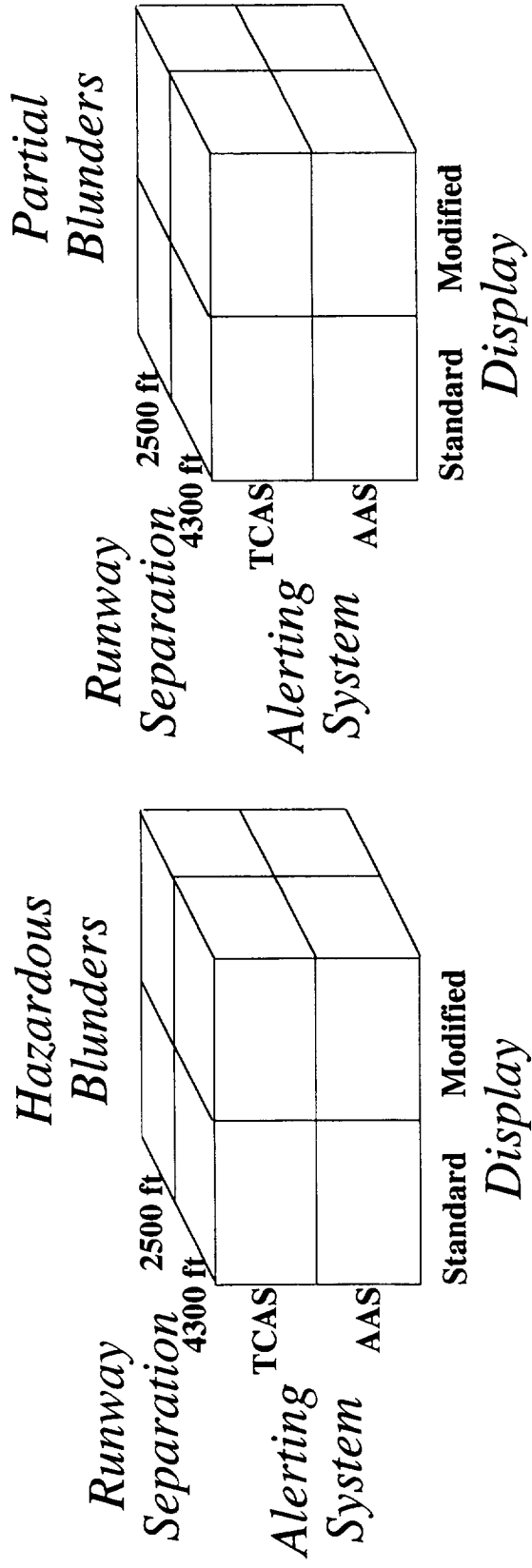
- Escape maneuver flown manually: Auto-pilot disconnected, collision avoidance syst (CAS) guidance supersedes active flight-director guidance from AFS.
- No Collision Avoidance / AF System Integration: Current design where AFS modes, defaults and transitions are independent of airborne CAS.
- Modified Missed Approach Procedures: Subject aircraft continues on runway heading course or returns to runway heading course after successful conflict resolution.
- Part-Task Research Platform Suitable: Medium fidelity simulation, generic Glass Cockpit (EFIS) environment with integrated scenario generation and data-collection.
- Minimum Training Desirable: approx 2 hour duration.



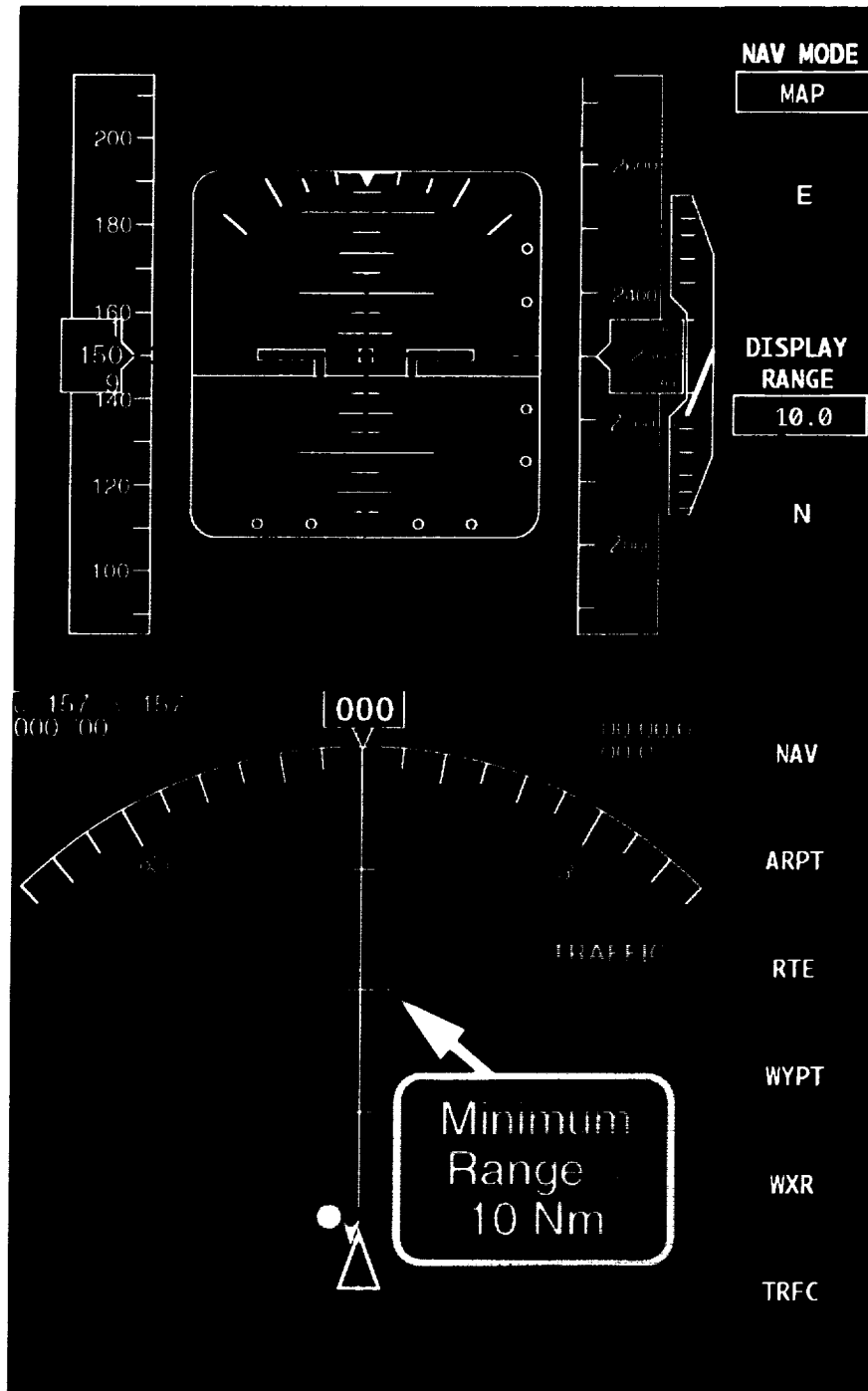
Approach

Experiment Design

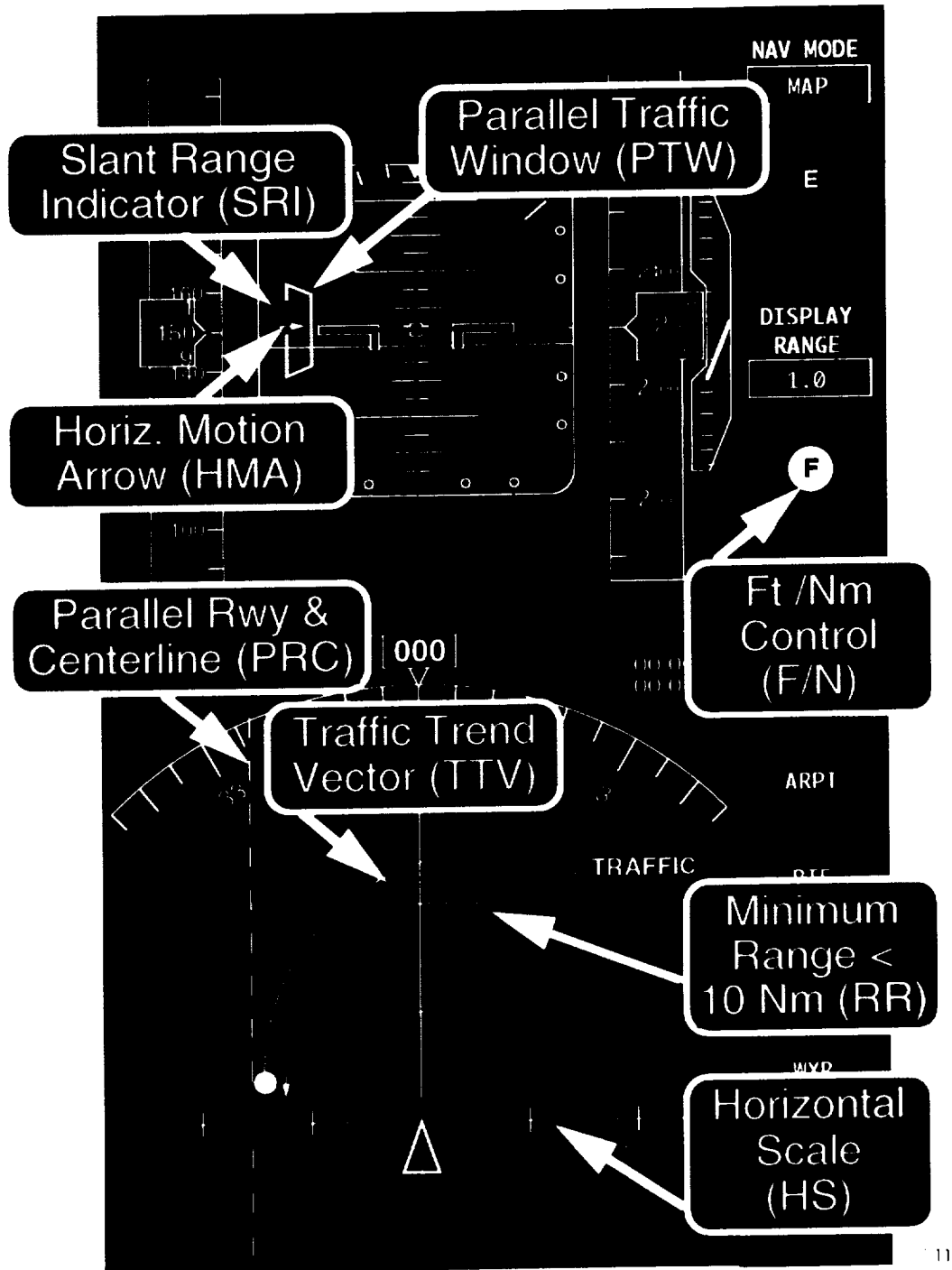
- 20 Subjects
- Scenarios presented in Display/Alerting System sets. Within each set, Rwy Sep and Blunder Type were varied. One additional NO-blunder scenario was added to each set, resulting in 20 separate scenarios for each subject



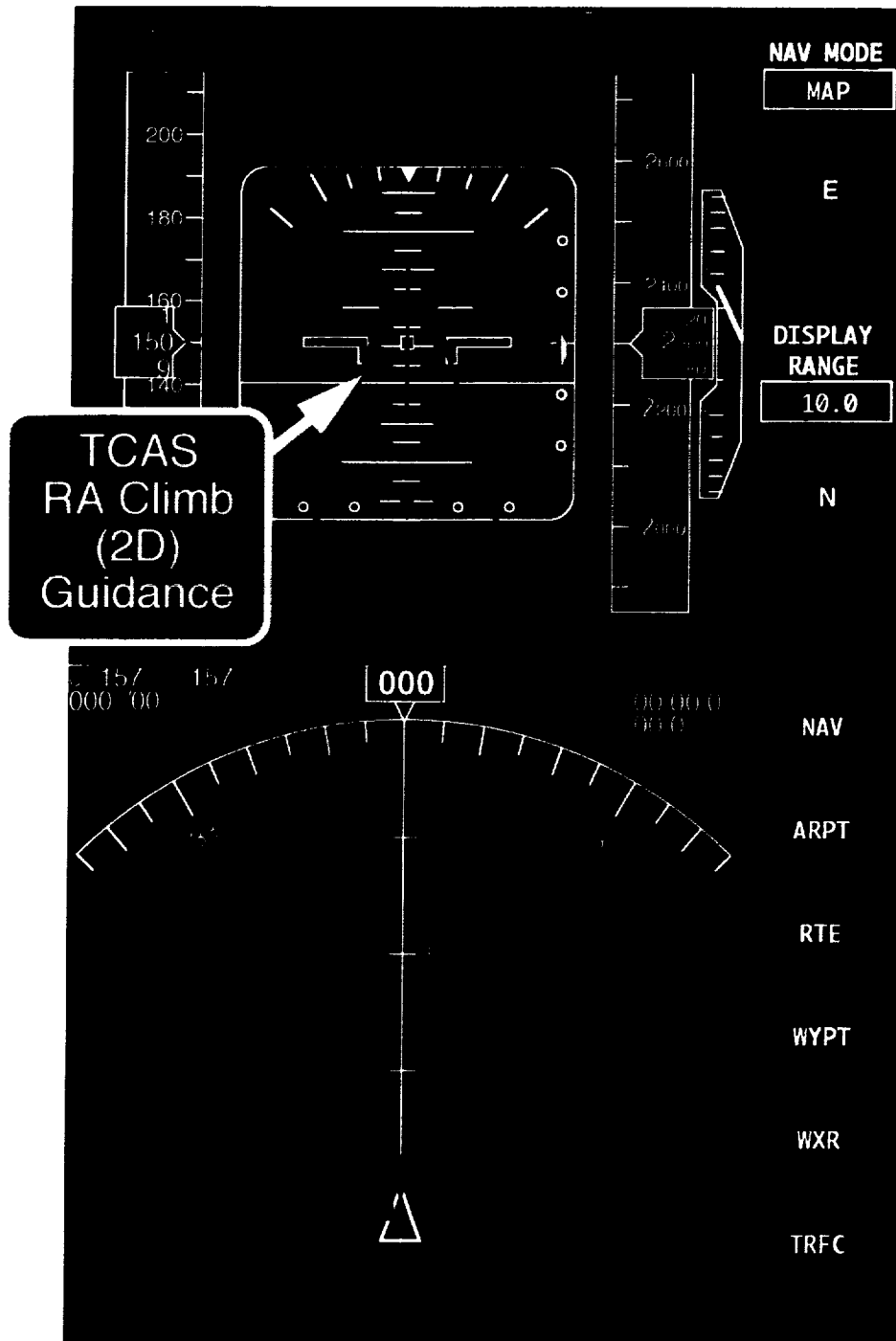
Traffic Alert, Standard Display Condition



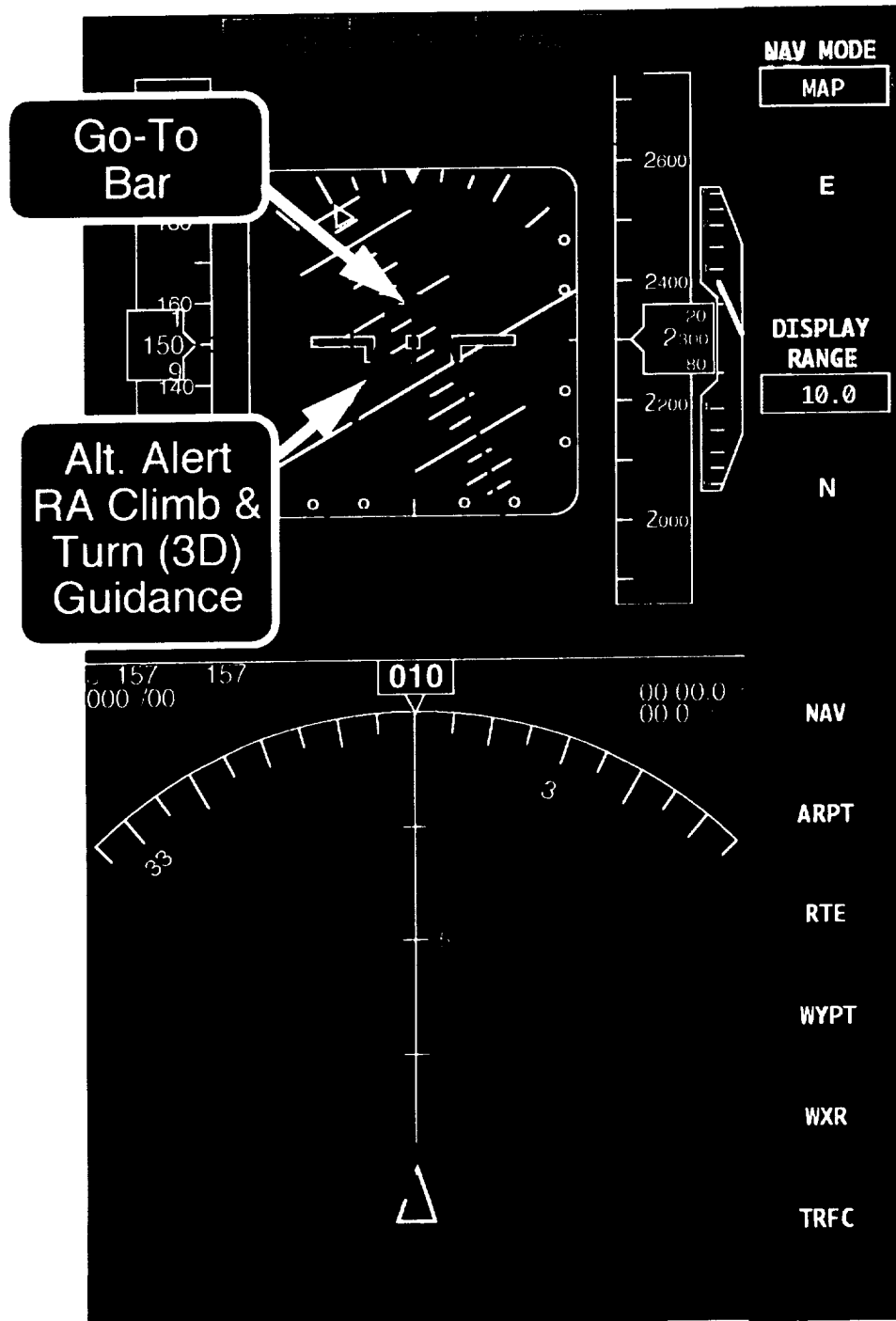
Traffic Alert, Modified Display Condition



Resolution Advisory, TCAS Alerting System, Standard Display Condition



Resolution Advisory, Alternate Alerting System, Standard Display Condition



13



Approach (cont'd)

Subjects

- All from a single, major air-carrier providing uniformity of procedures and training. Each pilot received all independent variables (within subjects design)

	Captain	First Officer	
737-300/500	2	3	25%
757/767	6	2	40%
747-400	5	2	35%

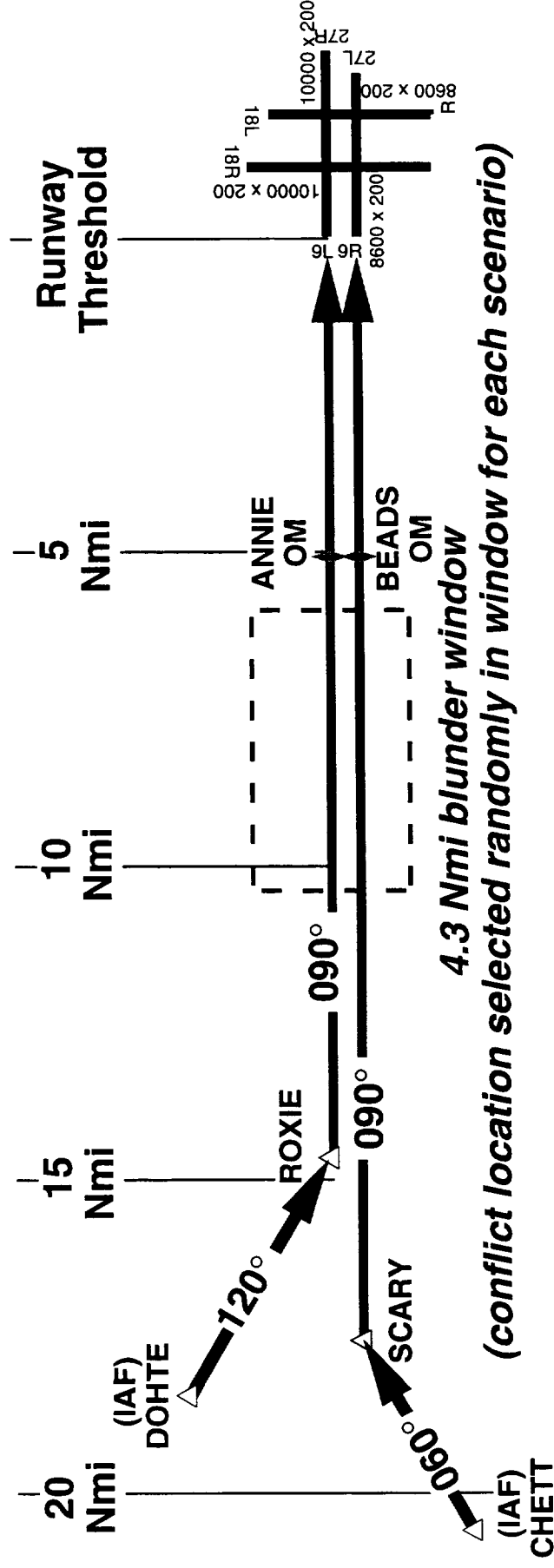
65% 35%

Mean Total Flight Hrs: 13,665 Mean # of RA's: 4.4



Approach (cont'd)

Scenario Geometry



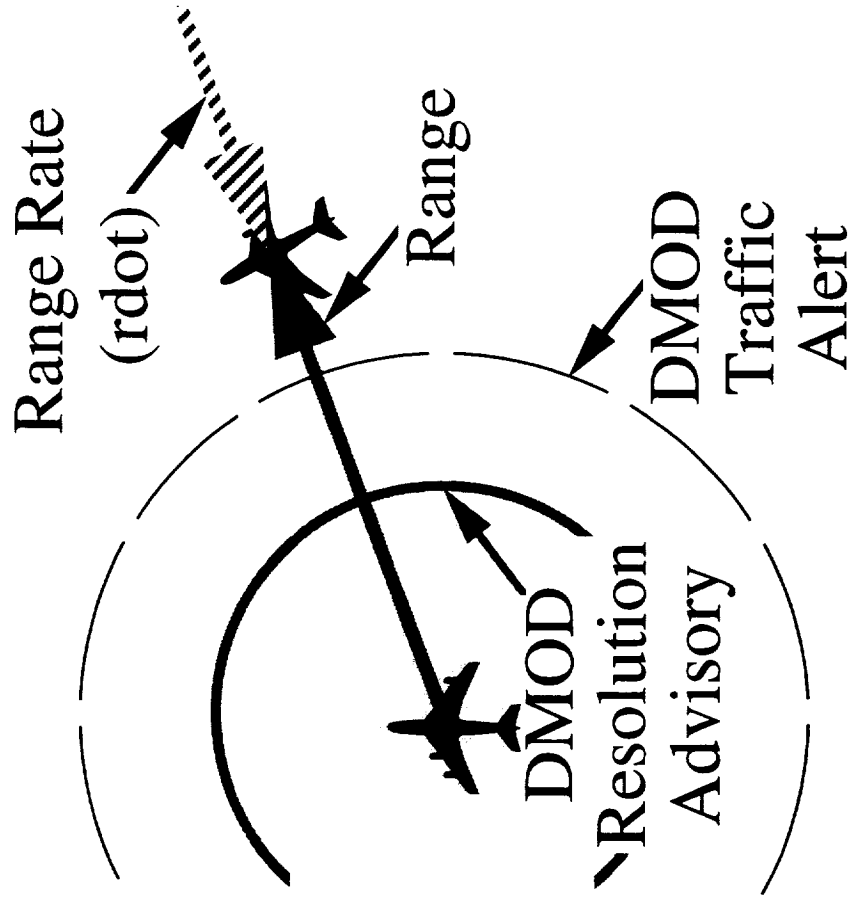
- Four fictitious airports, each with sets of paired runways separated by 4300 ft and 2500 ft.
- Runway stagger provided three geometry conditions



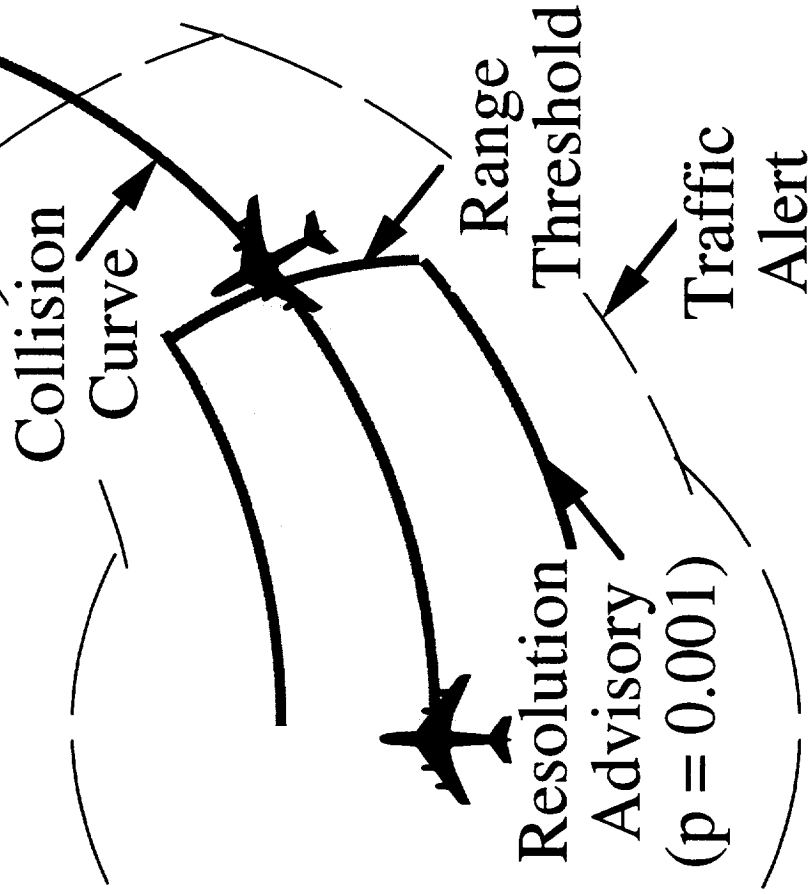
Approach (cont'd)

Alerting Systems - Threshold

TCAS



AAS

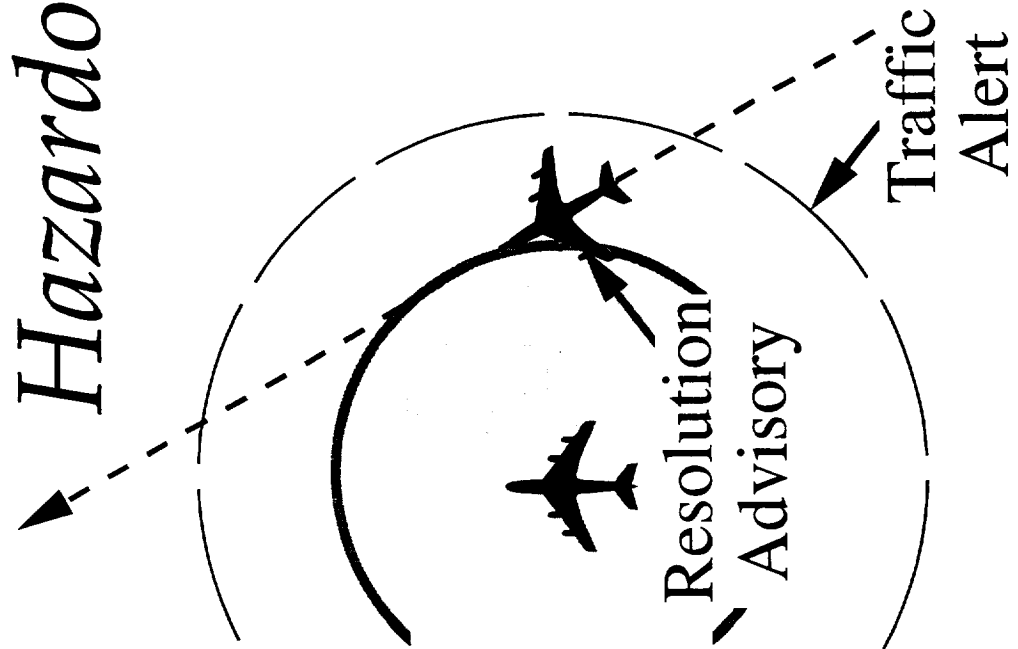




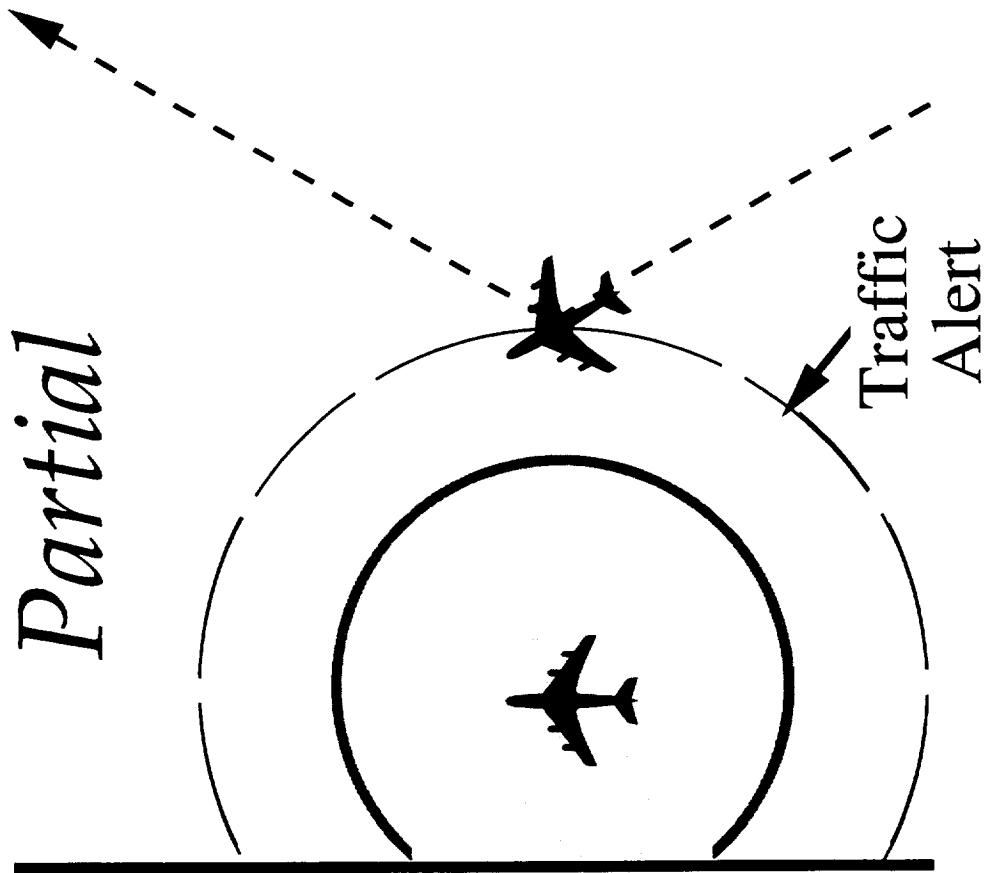
Approach (cont'd)

Blunder Type

Hazardous



Partial





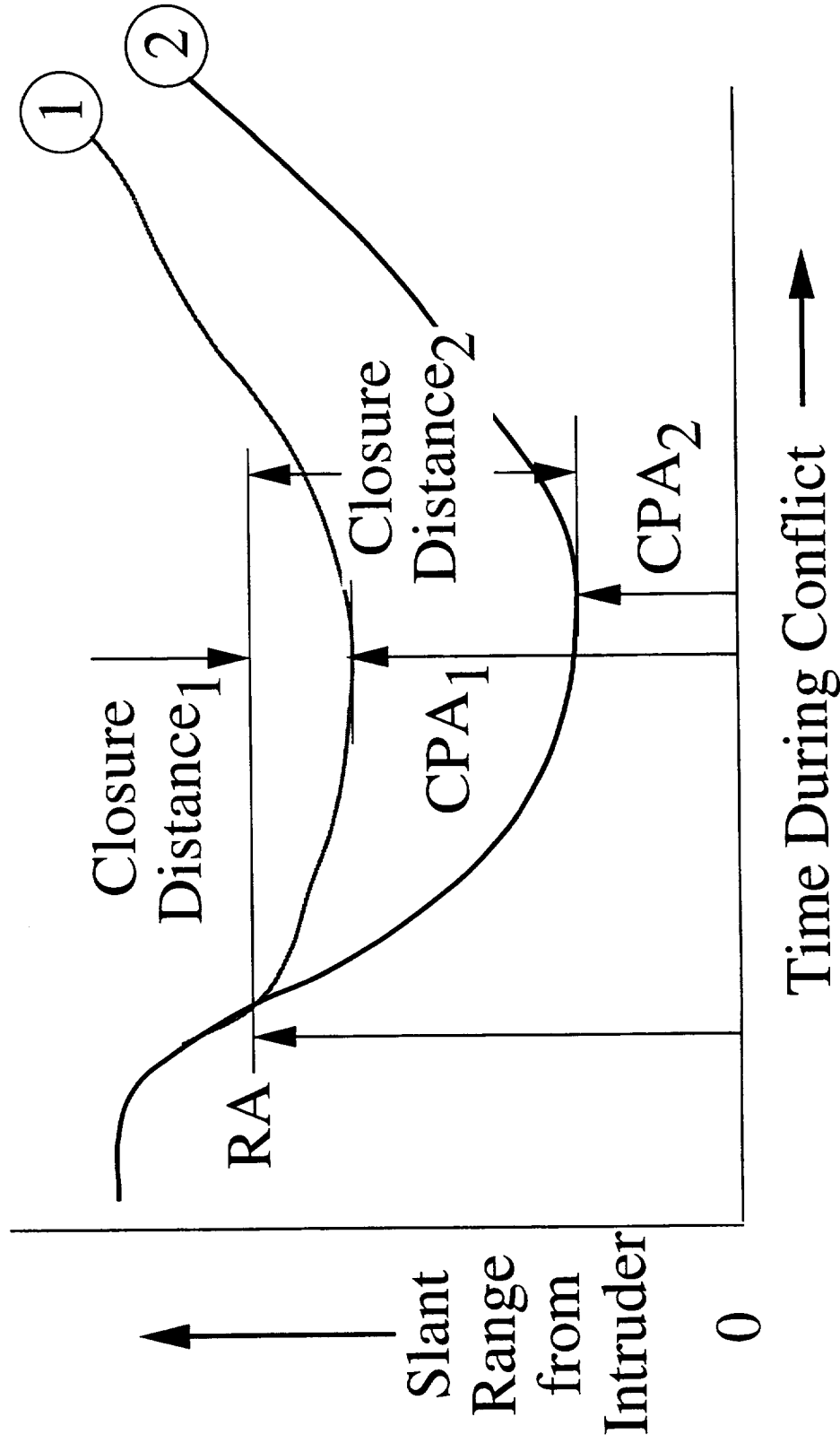
Measures

- Closest Point of Approach (Slant RangeCPA):
alerting system/pilot effectiveness to maximize range
- Closure Distance Metric (Slant Range_{RA} - SRangeCPA):
alerting system/pilot effectiveness to minimize closure
- System Reaction Time to Conformance:
time to initially satisfy conflict resolution requirements
- Conformance:
properly satisfy system guidance commands
- Pilot False Alarm / Early Evasion:
avoidance maneuver is performed without/before an RA
- Subjective Measures
pilot ratings regarding display/element comparisons



Measures (cont'd)

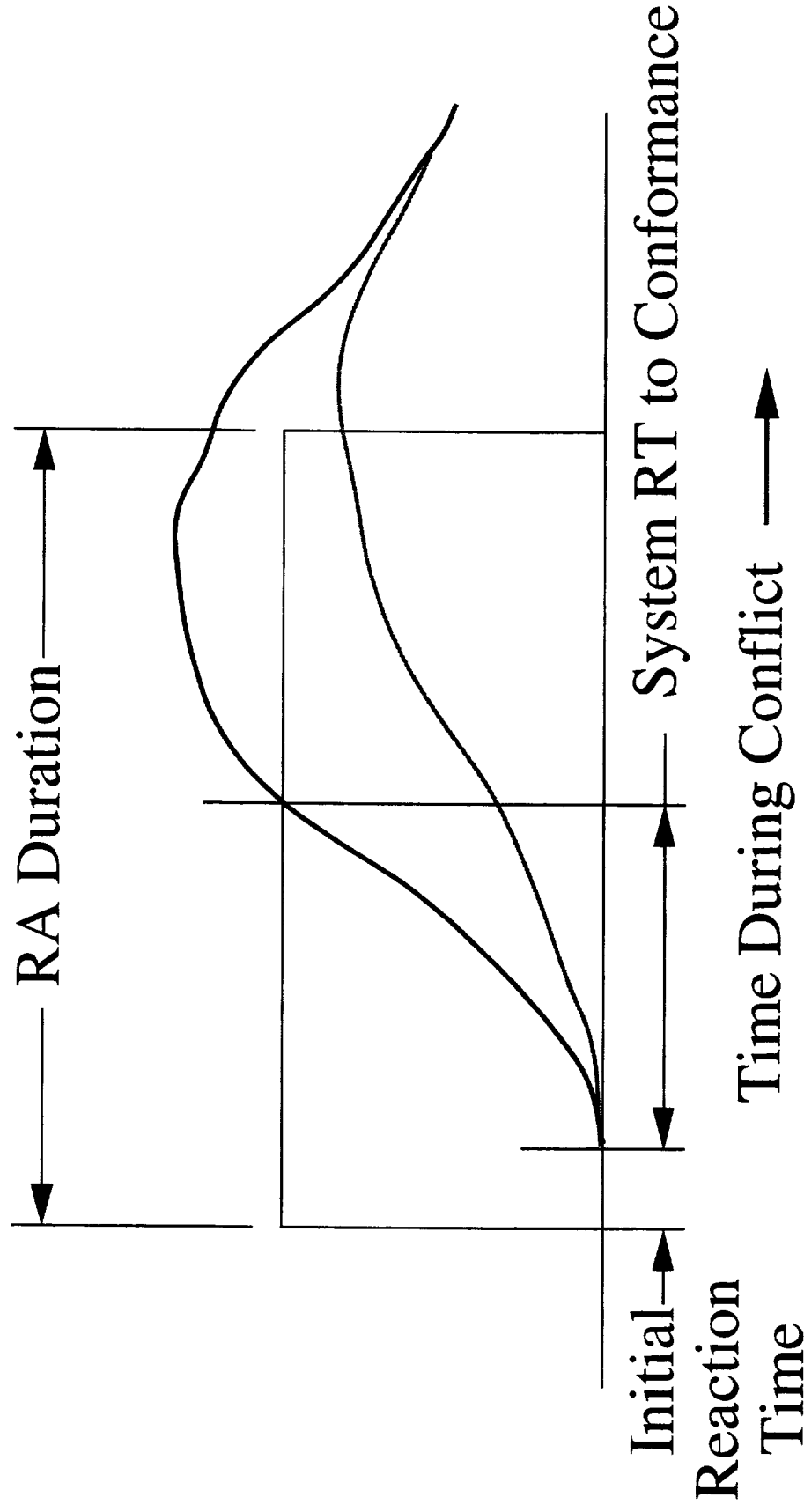
CPA and Closure Distance





Measures (cont'd)

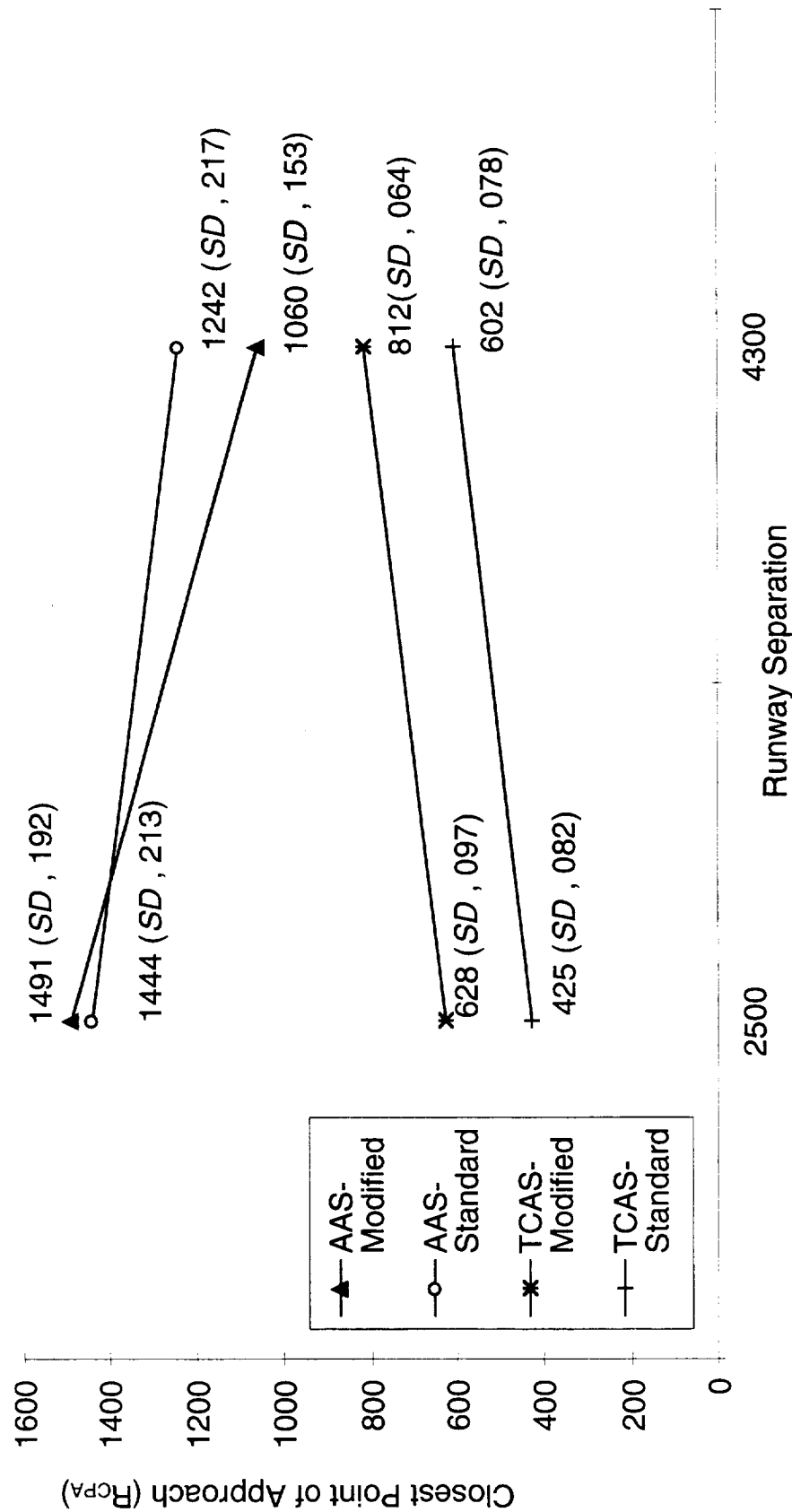
Conformance & Reaction Time





Results

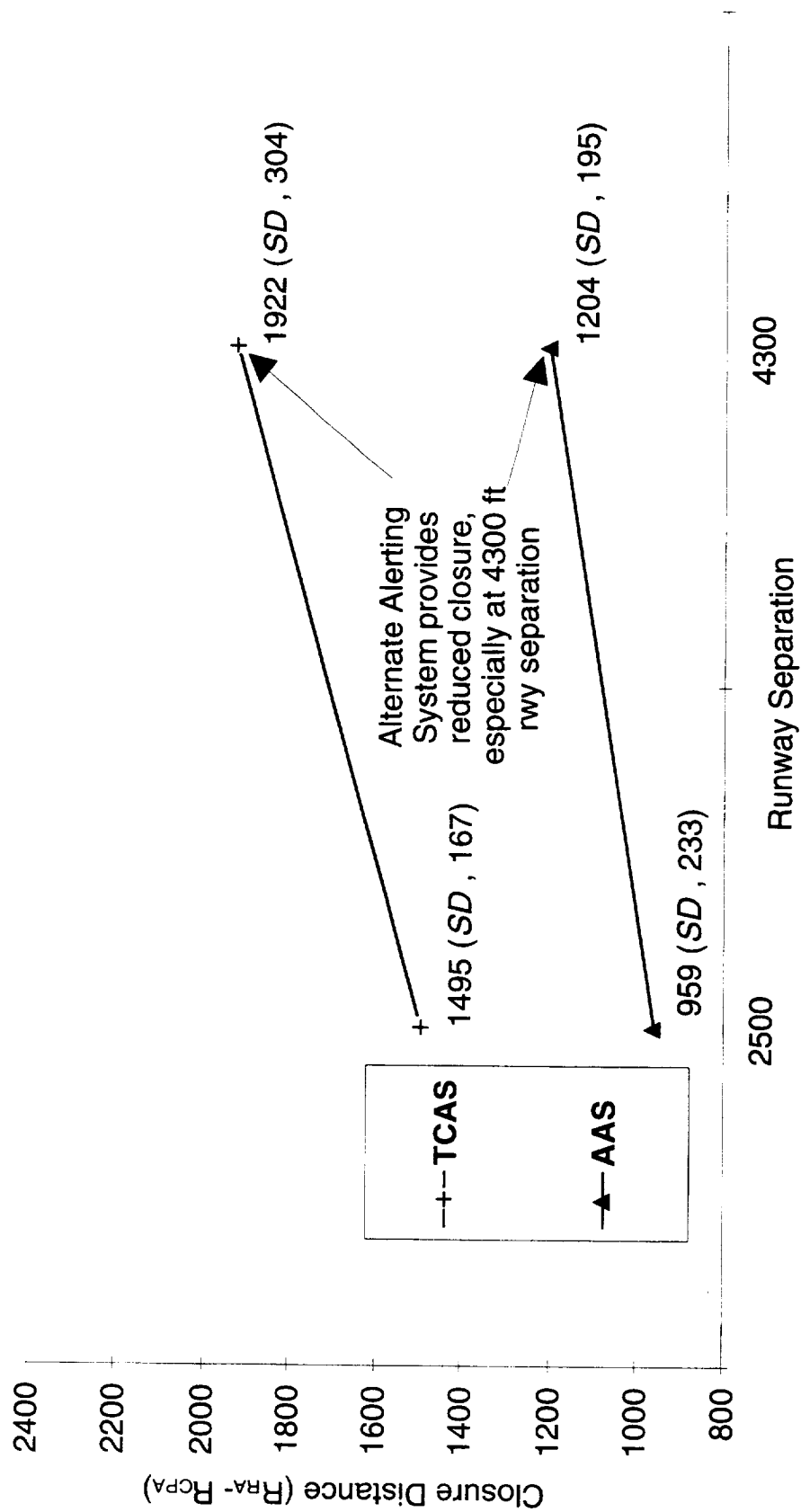
Closest Point of Approach





Results (cont'd)

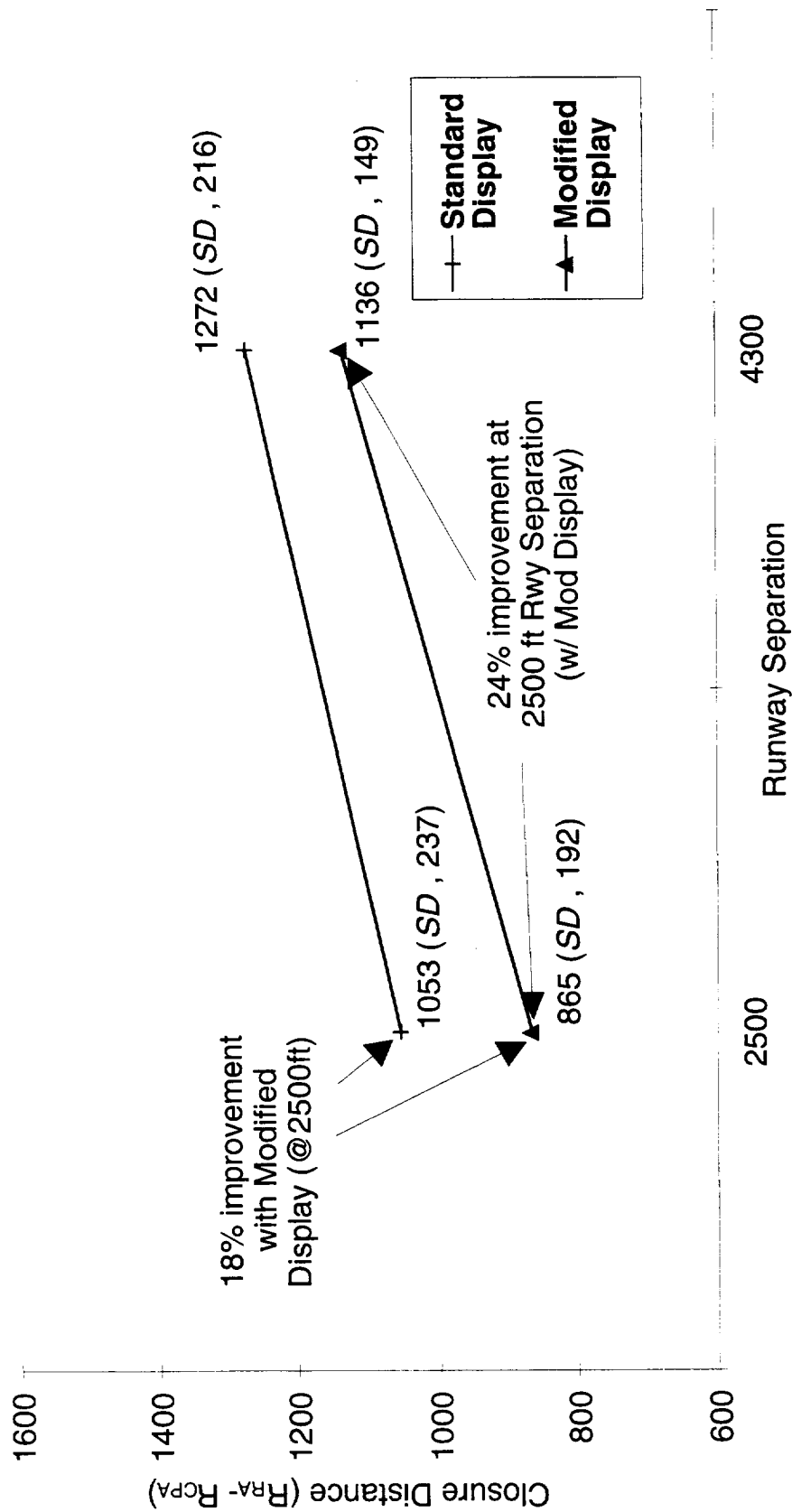
Closure Distance Metric (1)





Results (cont'd)

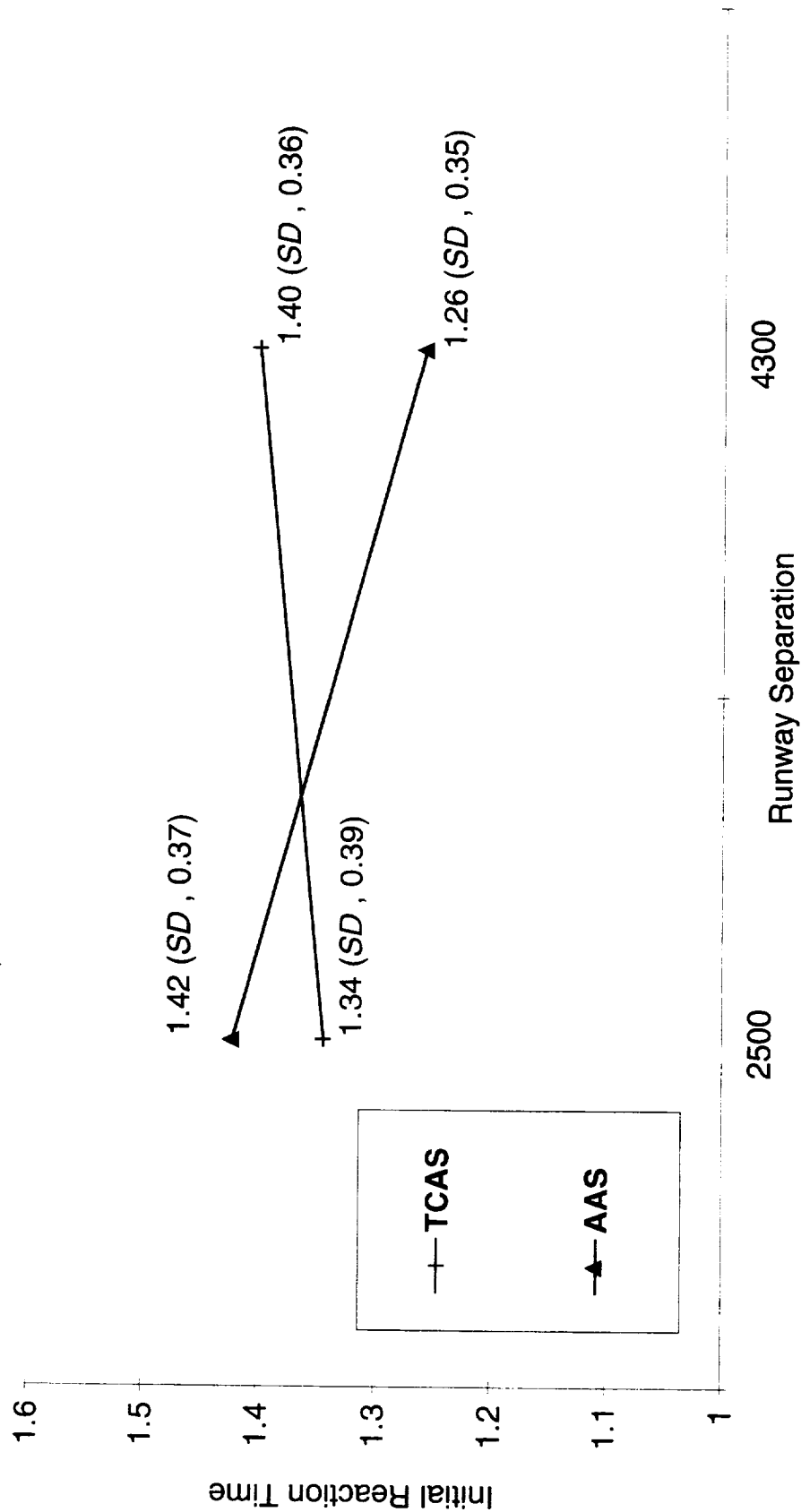
Closure Distance Metric (2)





Results (cont'd)

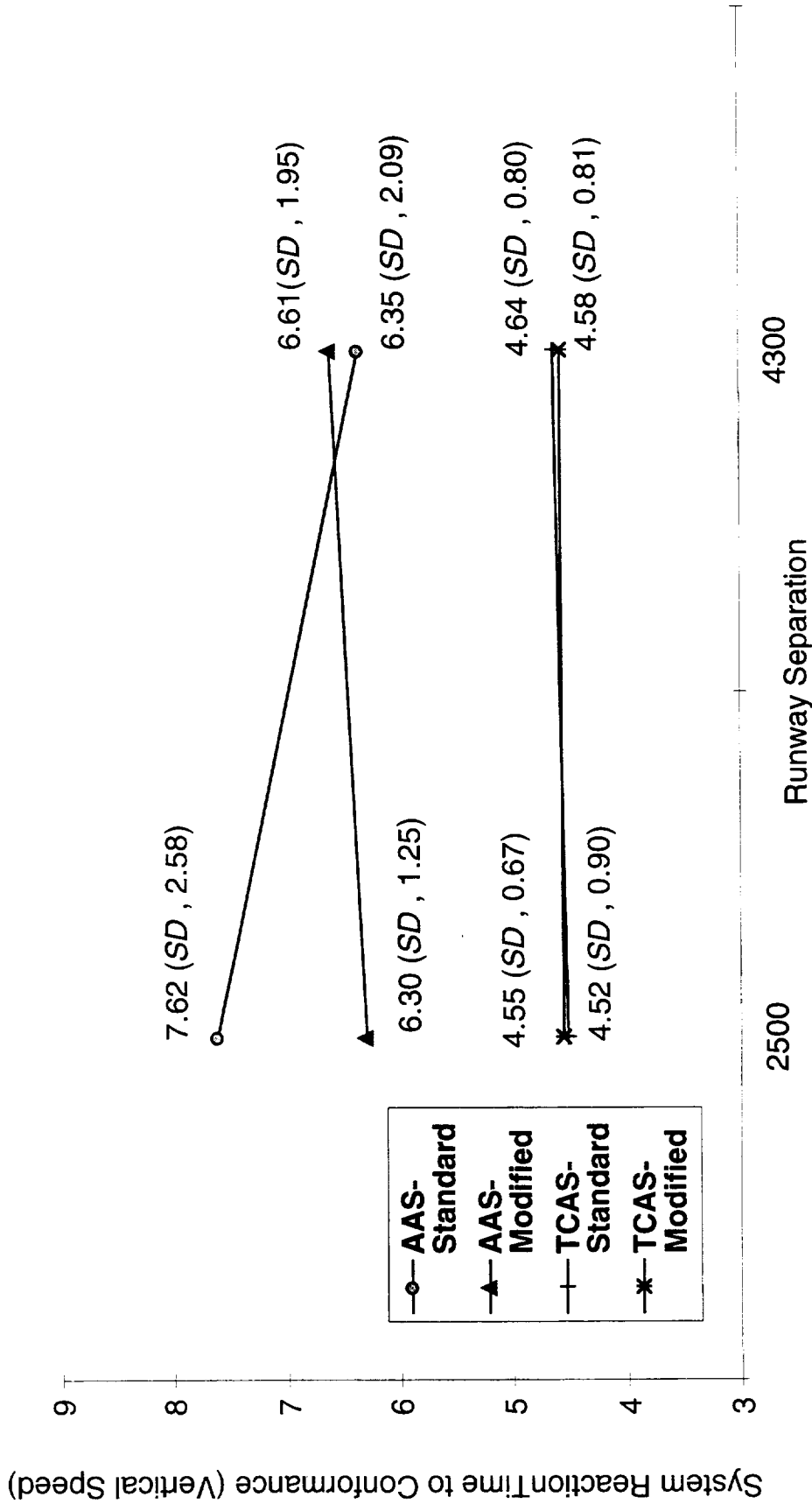
Initial Pilot Reaction Time





Results (cont'd)

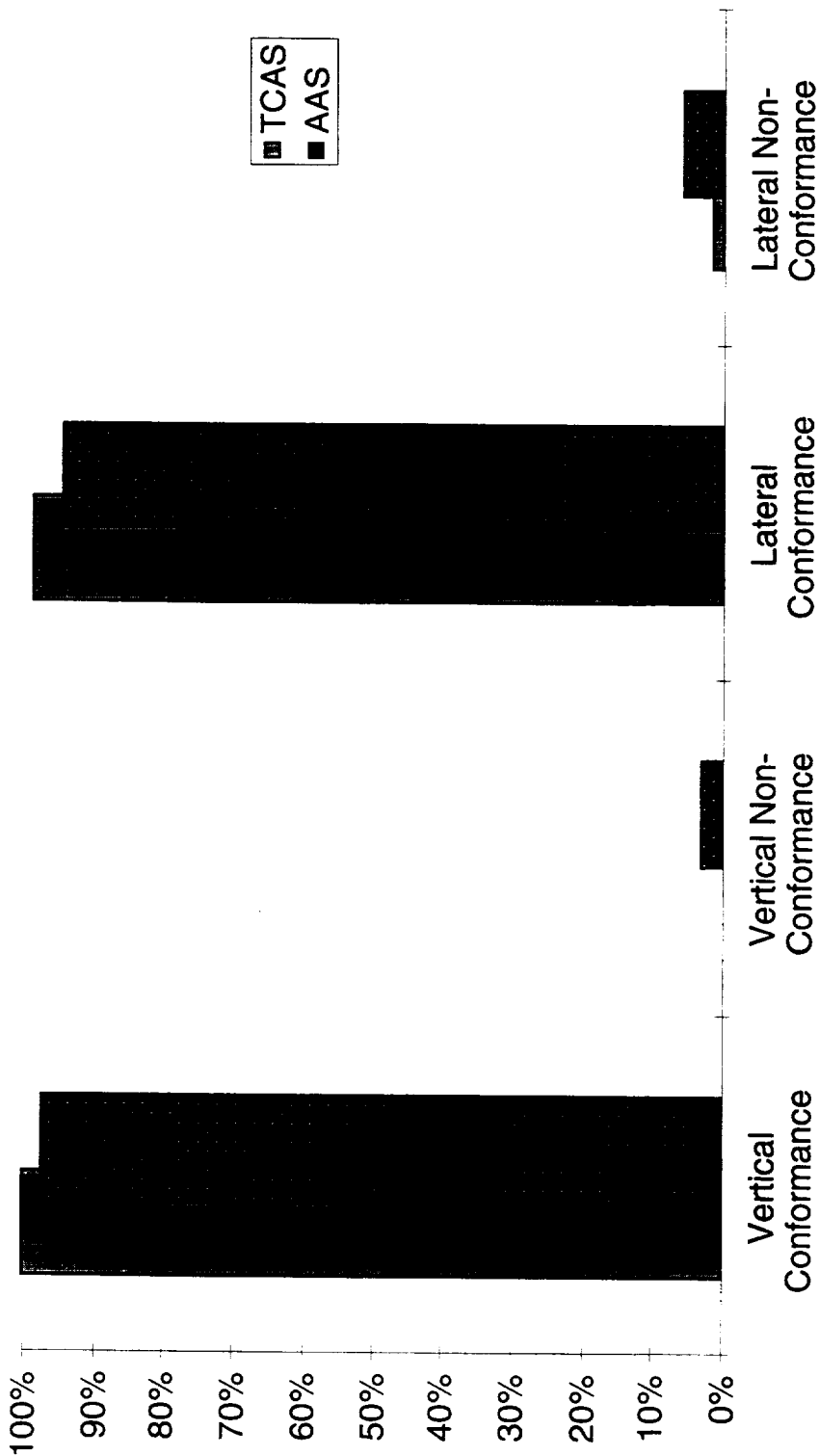
System RT to Conformance (VSP)





Results (cont'd)

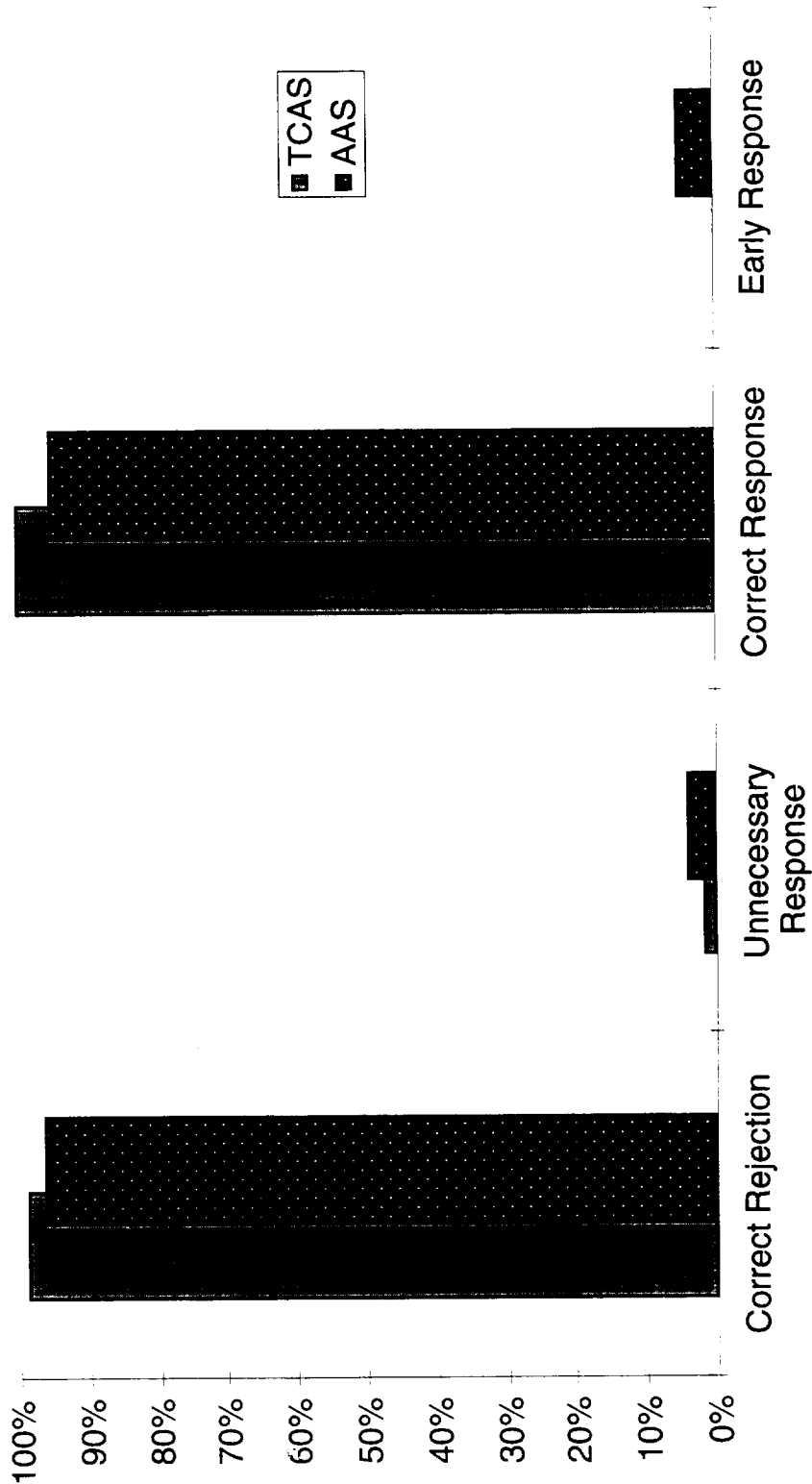
Conformance





Results (cont'd)

Pilot False Alarm / Early Evasion

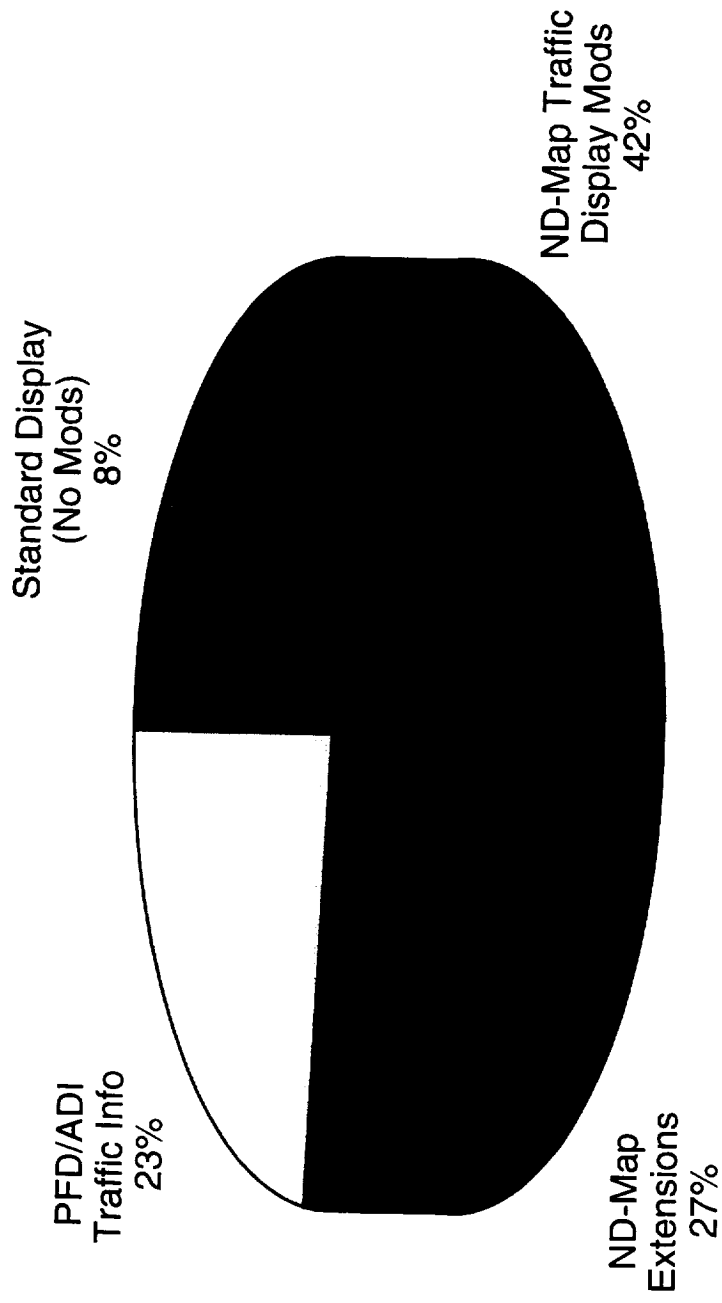




Results (cont'd)

Subjective Measures (1)

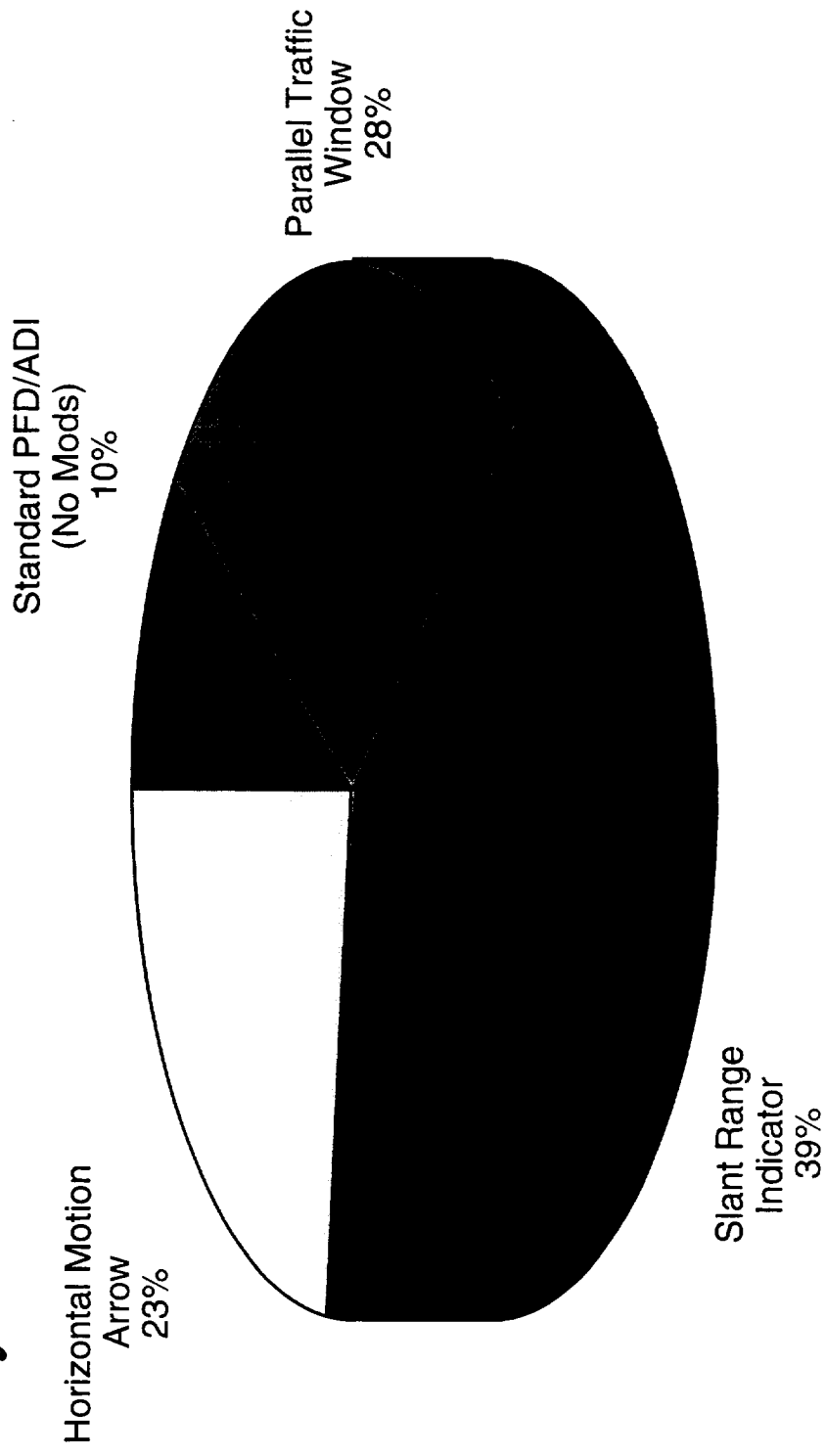
- Which display combination was more useful in conducting approaches to closely-spaced runways?





Subjective Measures (2)

- Which PFD/ADI traffic display information was more useful in conducting approaches to closely-spaced runways?

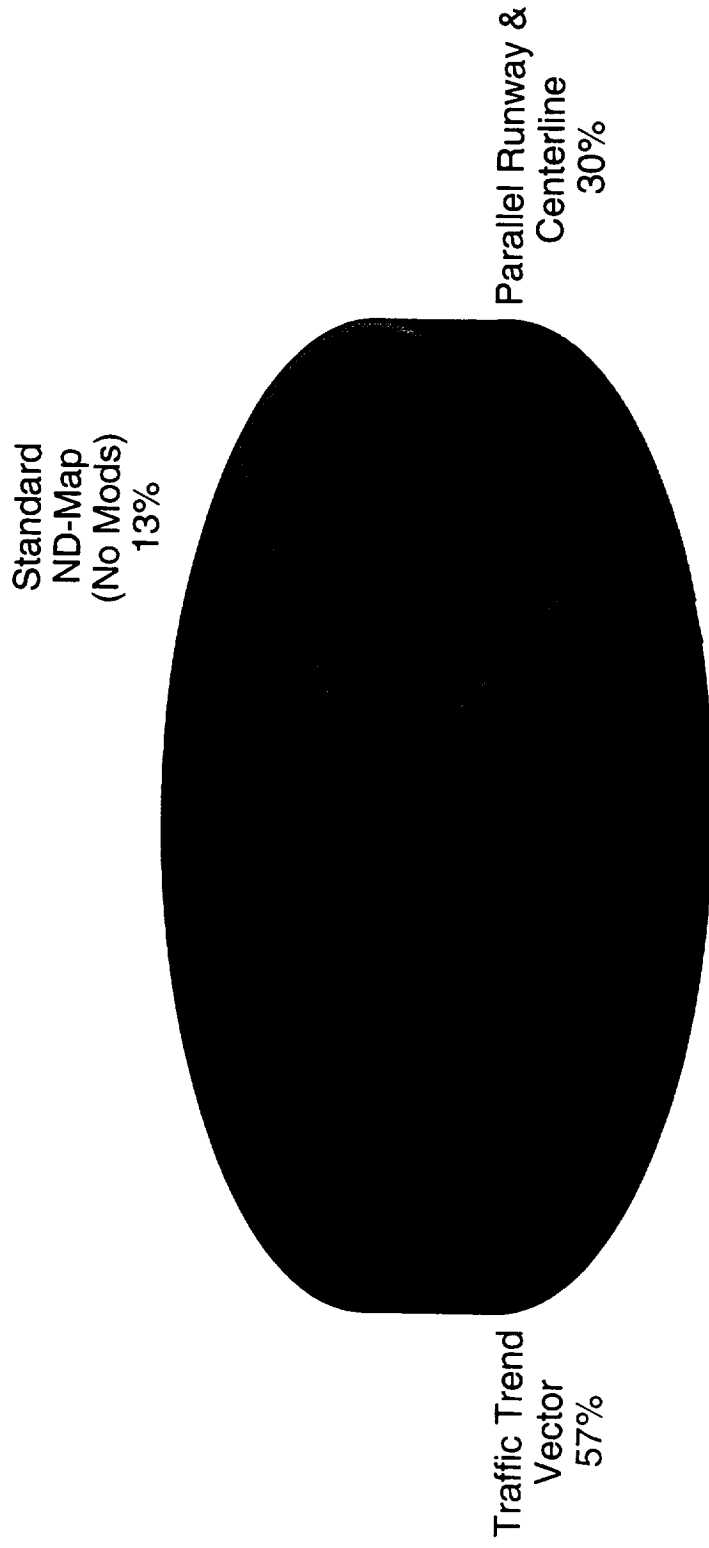




Results (cont'd)

Subjective Measures (3)

- Which ND-Map traffic display information was more useful in conducting approaches to closely-spaced runways?

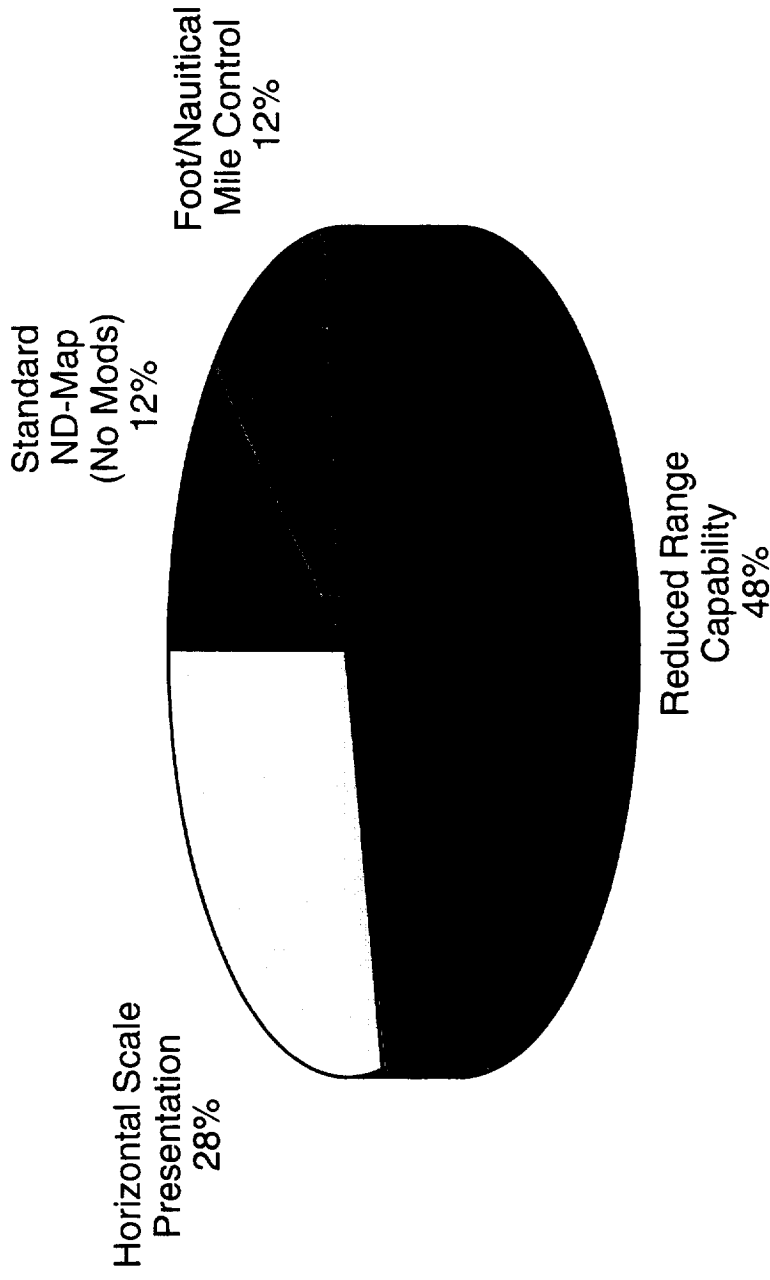




Results (cont'd)

Subjective Measures (4)

- Which ND-Map display extension was more useful in conducting approaches to closely-spaced runways?





Conclusions

- AAS provided greater aircraft separation than TCAS.
- For AAS, the Modified Displays provided greater aircraft separation than the Standard Displays.
- It took pilots longer to satisfy the vertical commands for AAS than for TCAS. Time to satisfy the lateral commands was about the same as vertical for AAS.
- When using TCAS, guidance conformance was satisfied in nearly 99% of the maneuvers flown by the pilots.
- When using AAS, guidance conformance, and the number of false alarms / early evasions, were only slightly worse than when using TCAS.
- Pilots preferred the Modified Displays, especially the Traffic Trend Vector and Reduced Range capability.

Flight Deck Centered Independent Closely Spaced Parallel Runway Operations in Instrument Meteorological Conditions, Phase II

Charles Scanlon and Marvin Waller
NASA Langley Research Center
October 1996

CHS d:\aifs\sim4.ppt

Program Goal

Apply modern technology to develop procedures, tools, etc. that will enhance safety enough to enable independent approaches to parallel runways with runway spacing less than the current certified 3400' spacing.

Assumptions

- Information between aircraft will be exchanged at least once per second (ADS-B)
- Precise navigation information like DGPS is used
- The worst case intrusion is a 30° interception
- A near miss is defined as an encounter with spacing less than 500'
- For analysis purposes, the intruder and evader will be considered to be at the same altitude

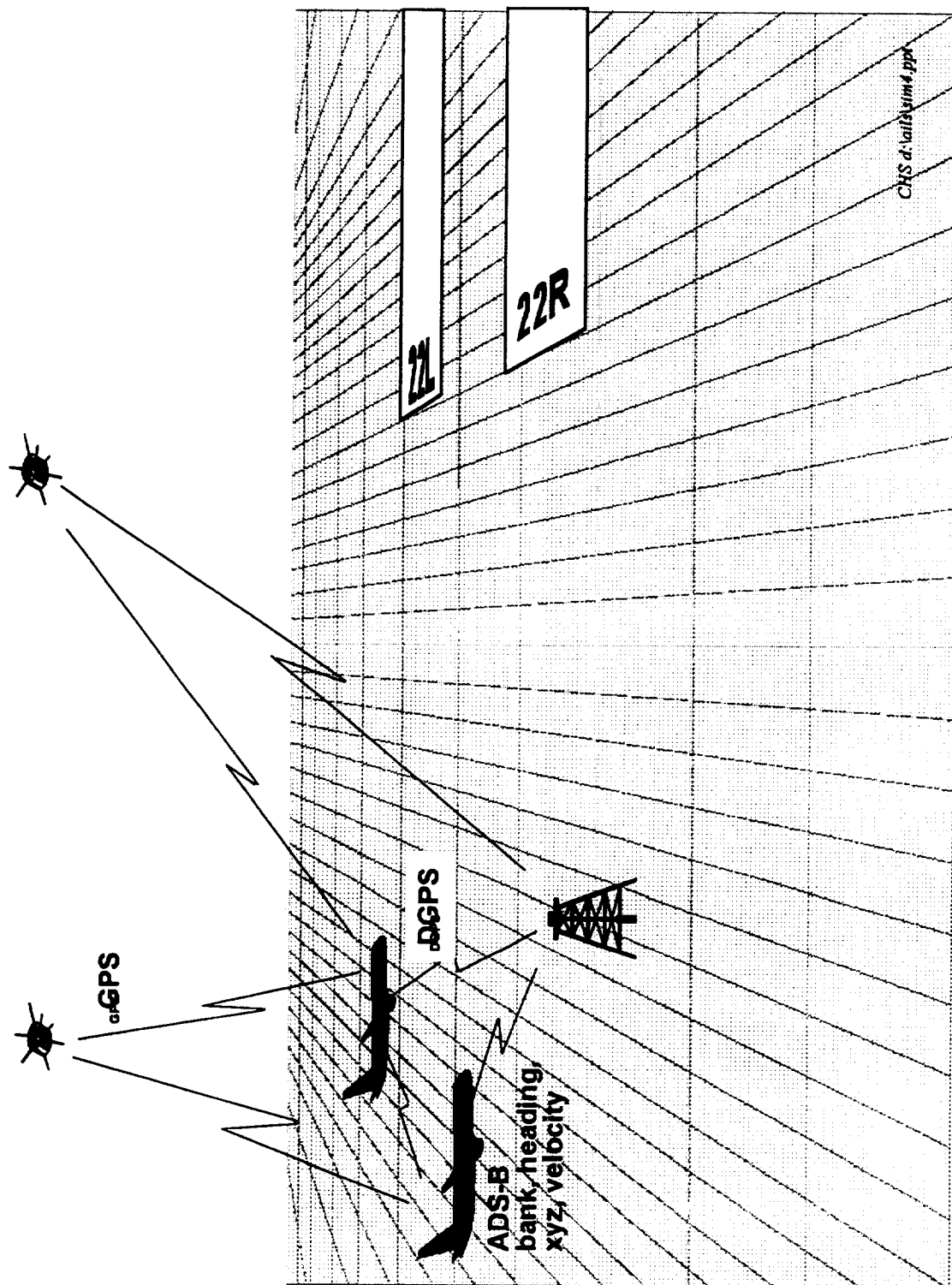
Approach

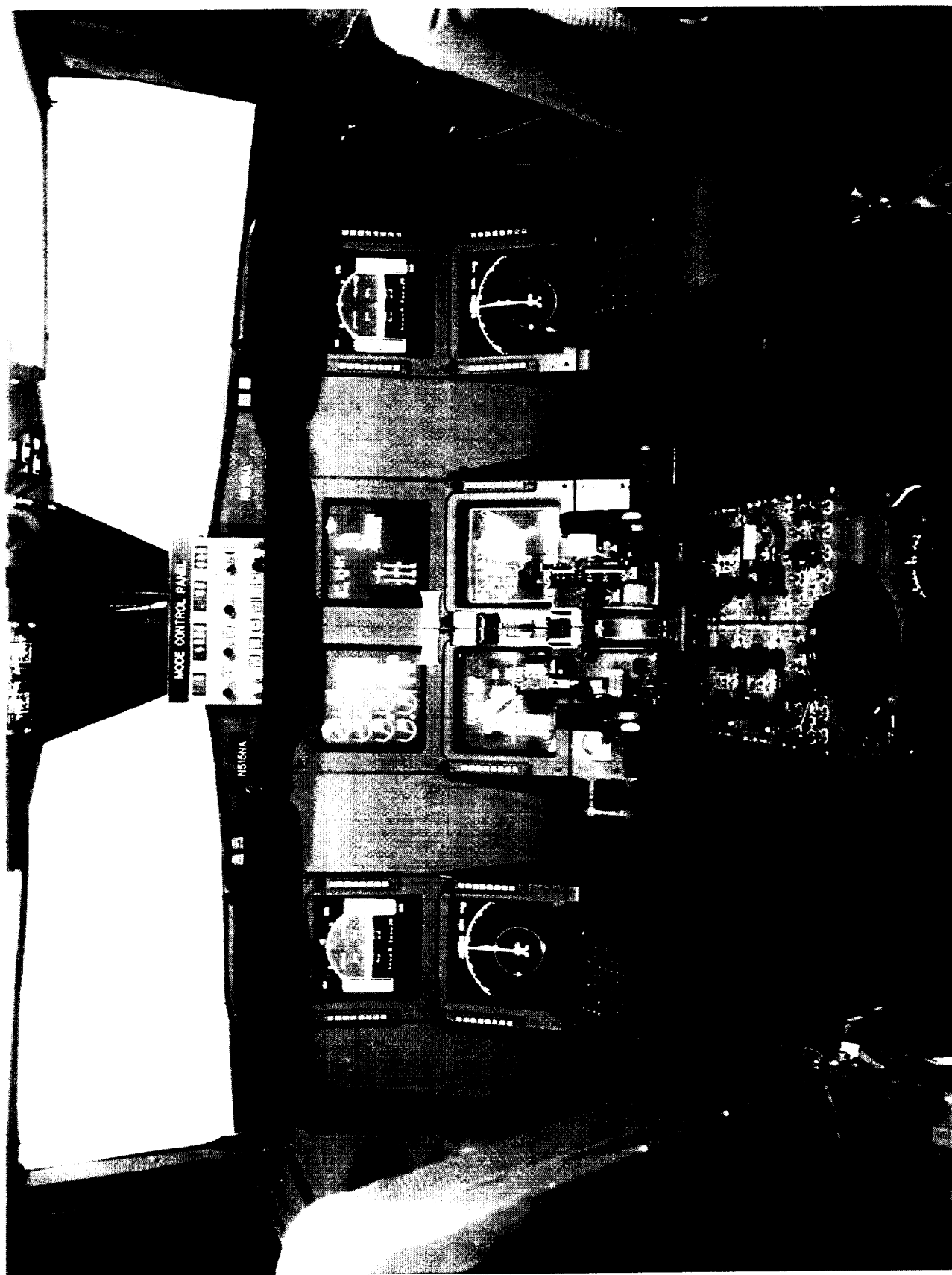
- Use the TSRV Simulator, an all glass cockpit operating with B737-100 flight characteristics
- Use two person test crews to get some measurement on crew procedures and acceptability
- Use alerts to help keep aircraft in their own airspace and keep from threatening aircraft on the parallel approach
- Use alerts and procedures to avoid a near miss in the event of an intrusion

Approach (Continued)

- Hand flown approaches with Flight Director and Auto Throttle
- TCAS used up to the 10 NM to threshold point, then AILS algorithms begin working
- Intruder scenarios hand flown with turbulence
- Test runs flown with turbulence and 10 kt direct crosswind

PARALLEL RUNWAY OPERATIONS CONCEPT



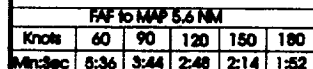


NASA Langley Research Center TSRV Simulator

CSP RWY 26L

DENVER INTL (DEN)
DENVER, COLORADO

120	150	180
2:48	2:14	1:52



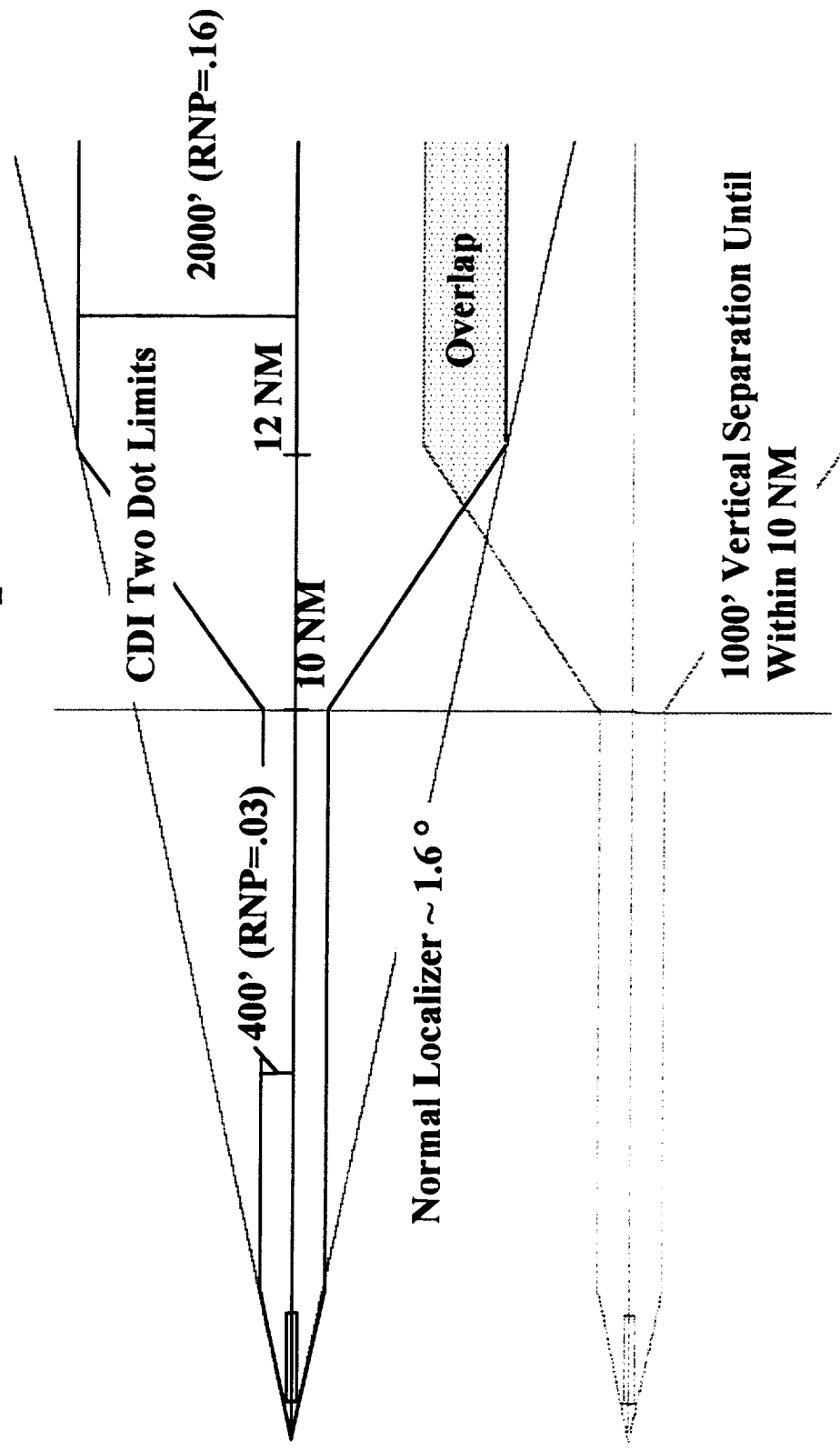
39° 52'N-104 °40'W

Phase II: Procedures and Alerts

- Each aircraft is required to stay within its assigned airspace and maintain a non-threatening attitude/track.
- In the event of an intrusion, an emergency escape climbing turn is mandatory.

Phase II: Required Navigation

“Rocket Ship”



The “Rocket Ship” Localizer

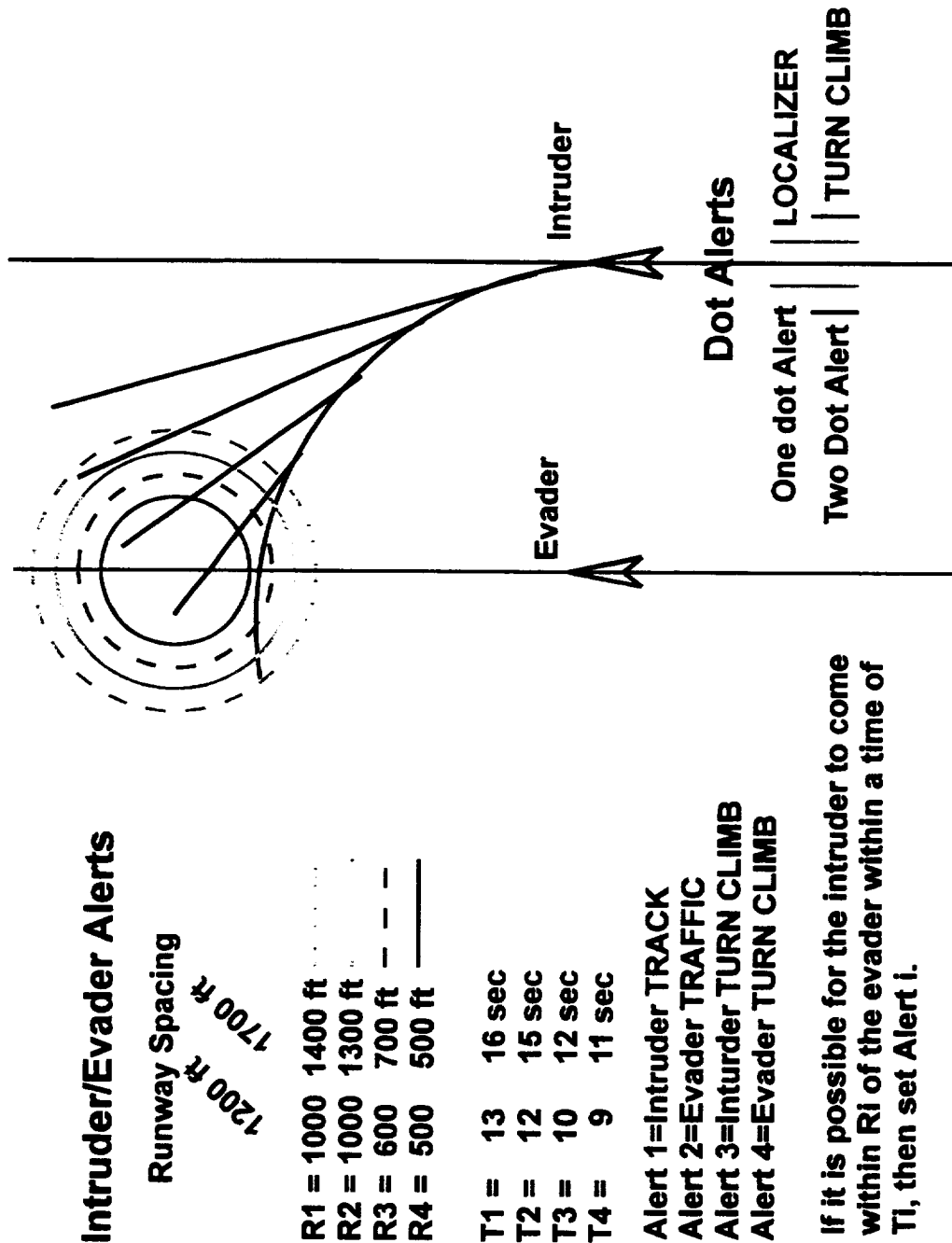
C. H. Scanlon

The normal Localizer of an Instrument Landing System (ILS) forms an angular beam with vertex at the localizer transmitter, usually 1000' beyond the far end of the runway and centered on the runway threshold. “The width varies between 3°-6°, tailored to provide 700 ft [width] at the [runway] threshold (full scale limited)”, Airman’s Information Manual, Section 1-10. In order to use a precision guidance system like Differential Global Positioning System (DGPS) to emulate an ILS, that precision guidance has to be programmed to the angular geometry of a normal ILS localizer.

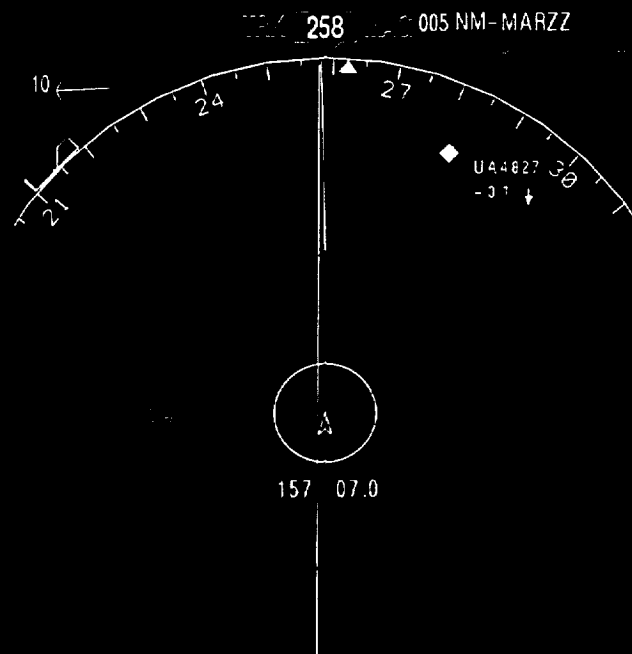
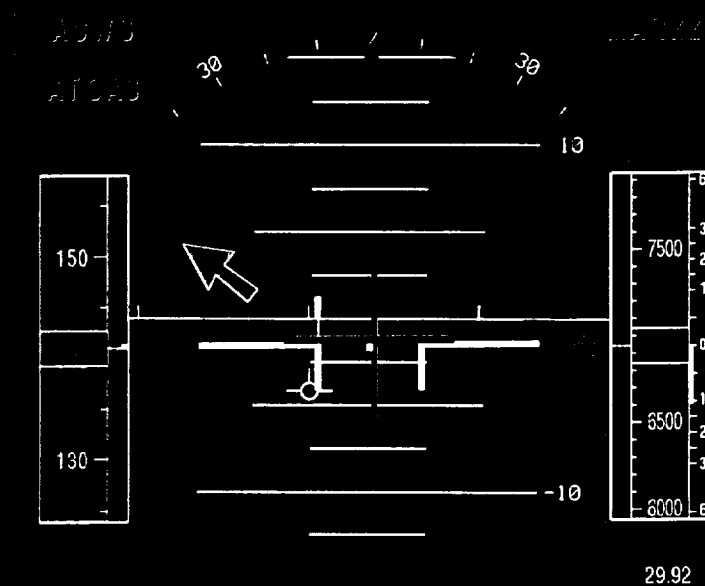
In the “Rocket Ship” (RS) geometry, the precision guidance Localizer is programmed to be linear for most of the approach. Using the runway centerline as the RS centerline, the RS is programmed to be ± 2000 ft wide from the 12 nautical mile point, as measured from the runway threshold, to infinity and ± 400 ft from the 10 nautical mile point to the approximate Middle Marker (where the ± 400 ft width matches a normal ILS Localizer geometry). The RS geometry gradually tapers from the ± 2000 ft width at 12 nautical miles to the ± 400 ft wide at the 10 nautical mile point. Inside the approximate Middle Marker location, the RS is programmed to be angular like a normal ILS Localizer.

Normally, aircraft would be “vectored” onto the approach outside the 12 nautical mile point so that the aircraft capture of the Localizer would take place in the wide (± 2000 ft) part of the RS. Glide Slope capture normally occurs inside the 10 nautical mile point, within the narrow part of the RS. The RS Glide Slope (GS) is programmed to be angular, just like a normal ILS GS.

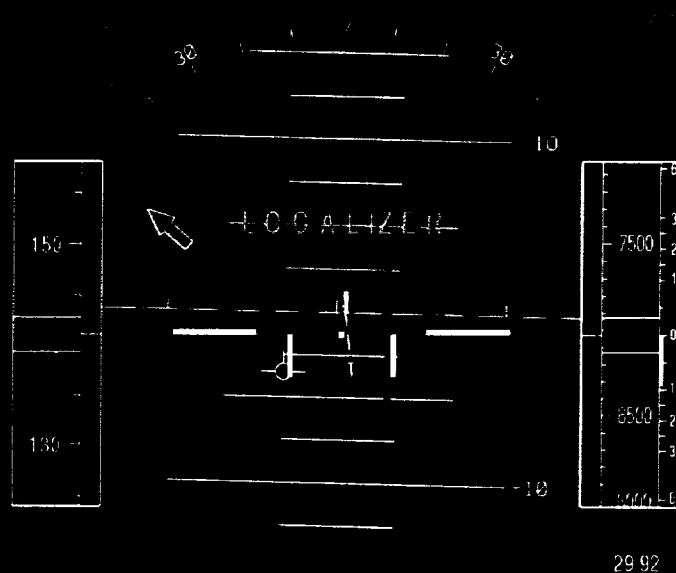
Phase II: AILS Alerts



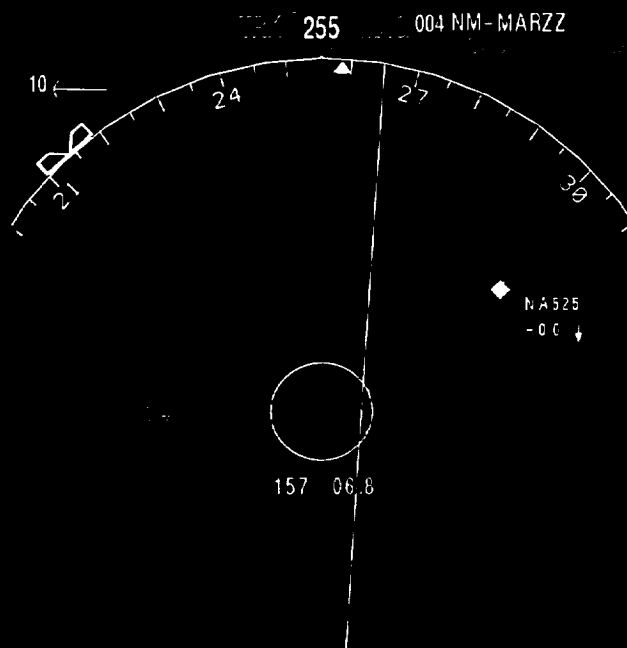
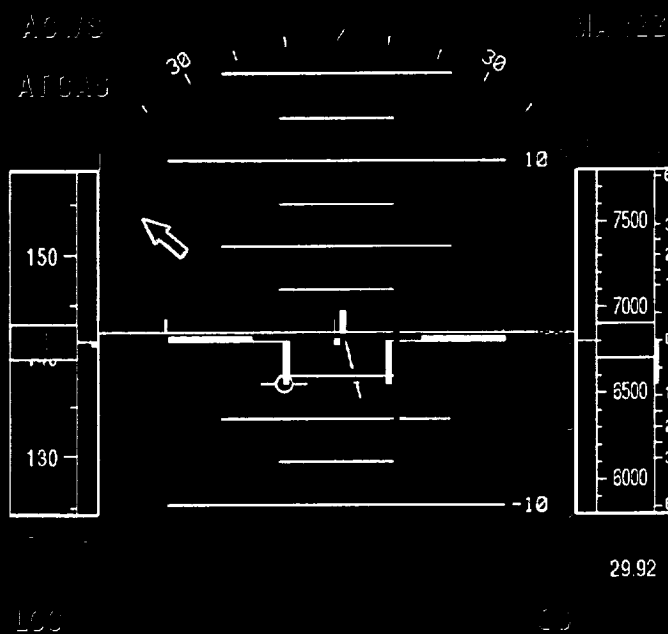
4 NM RANGE, NO ALERTS

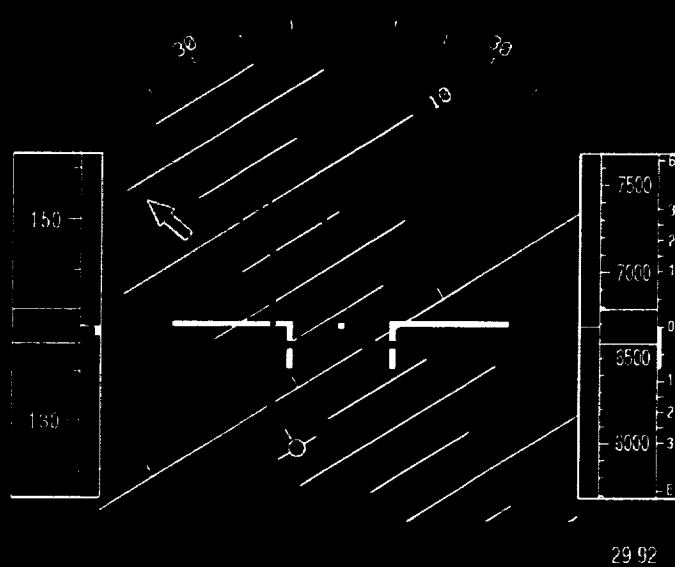


1 NM RANGE, ONE DOT ALERT

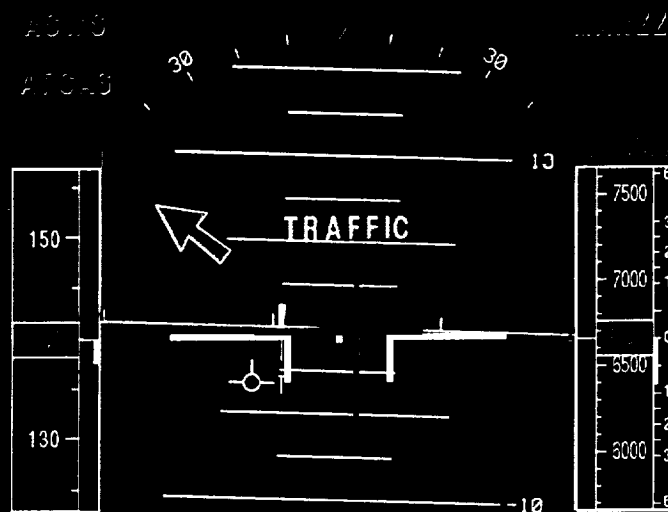


1 NM RANGE, TWO DOT ALERT



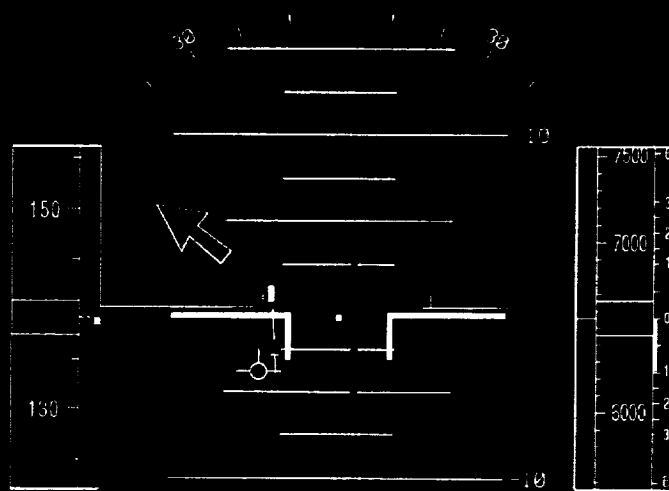


1 NM RANGE, TRAFFIC ALERT

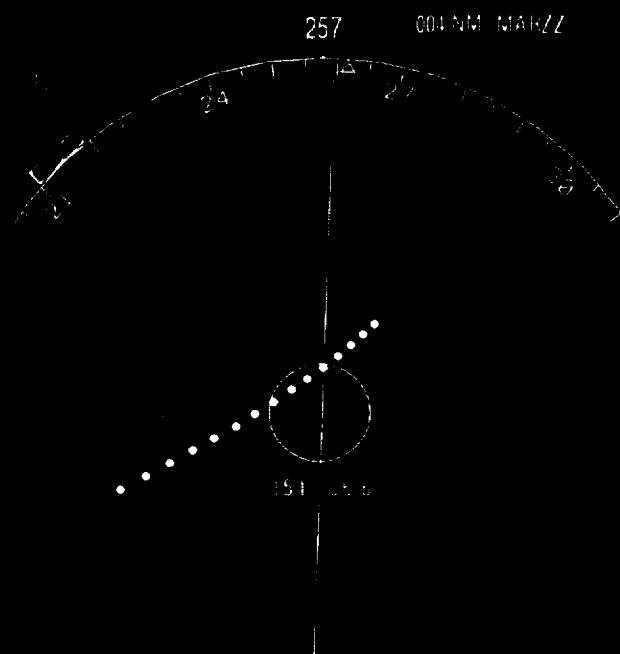


29.92





29.92



Phase II: Simulation Test Outline

- Eight two pilot test crews
- One day test per crew with 28 runs
- 1700' and 1200' spacings

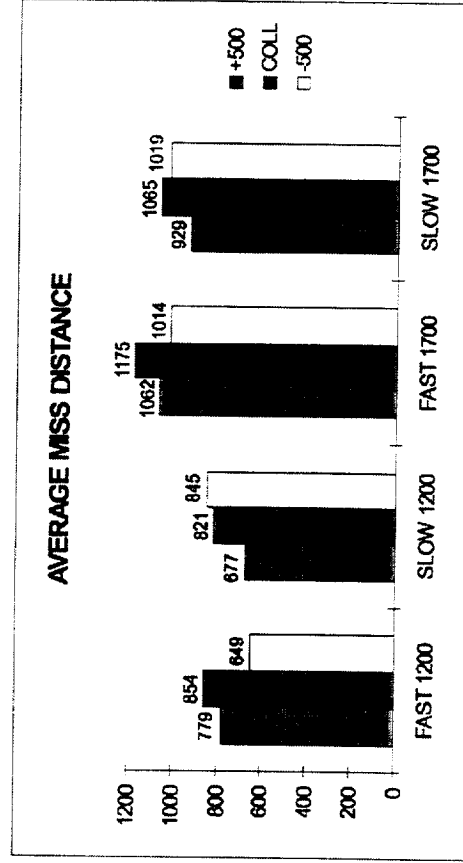
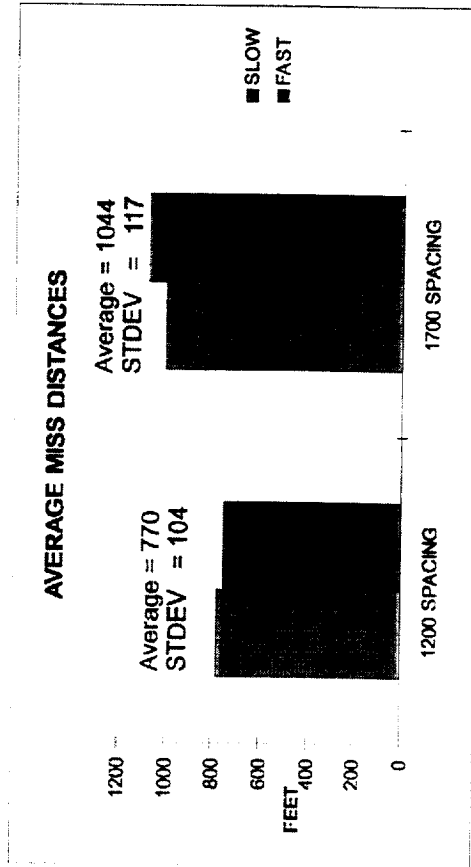
Phase II: Simulation Test Matrix

- Primary Experimental Variables
 - Two runway spacings (1700' and 1200')
 - Seven scenarios
- Secondary Experimental Variables
 - Two Relative Speeds
 - Two Approach Altitudes
 - Two Runway Orientations
 - Four Sync Points

Phase II: Ordering of Runs

- Each crew member flies all combinations of the primary variables ($2*7=14$) randomly chosen.
- The secondary variables were distributed among the runs so as to make each run unique. This distribution was counterbalanced to the extent possible.
- Crew members alternate pilot flying and pilot not flying.

Preliminary Data



Reaction Time:

Average = 0.82 sec

STDEV = 0.49

Near Misses:

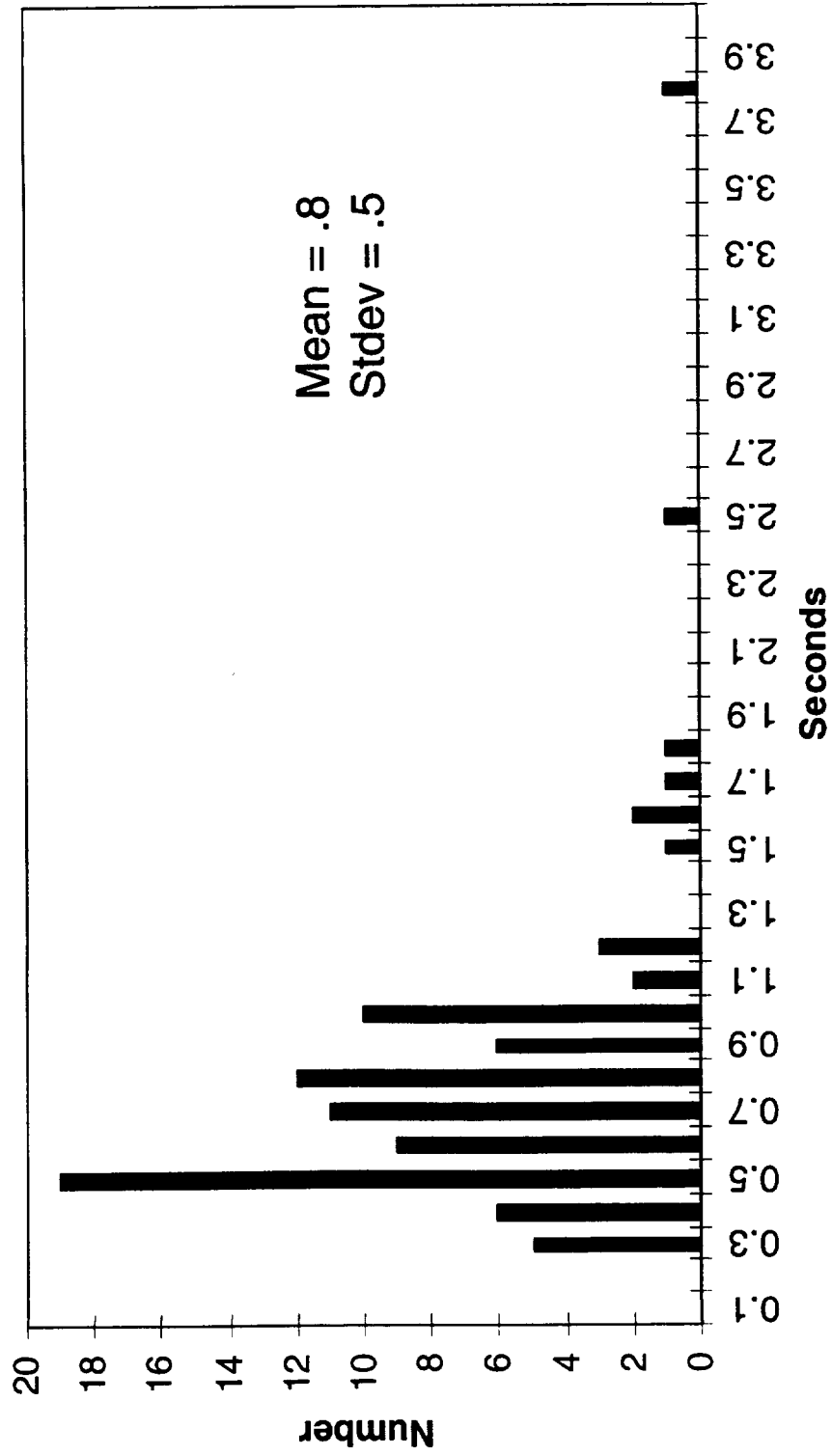
1700' = 0

1200' = 1*

Pilot opinion on "...would you fly...with spacings of:"
1700 ft: Yes: 15 No: 0
1200 ft: Yes: 14 No: 2

*** Actual 3D miss distance was > 500'**

Pilot Reaction Times



CHS d:\nails\sim4.ppt

Paired Approach Concept

**Rocky Stone
United Airlines**

**NASA Langley
Parallel Runway Workshop
10/29/96**

Objective

- ◆ Enable Multiple Arrival Streams in IMC to Airports With Closely Spaced Parallel

Runways

- ◆ Increase Capacity
- ◆ Safer Approaches in VMC

Airline Objectives

- ◆ Increase Capacity
- ◆ Minimize Delays
- ◆ Reduce Costs

Operational Concepts

- ◆ Independent Approaches
 - ◆ AILS Project
- ◆ Dependent Approaches
 - ◆ Paired Approach Concept

Why Dependent Approaches?

- ◆ Independent Approaches Can Not Provide Sufficient Capacity Benefits At:
 - ◆ SFO
 - ◆ SEA
 - ◆ EWR
 - ◆ STL

Paired Approach

- ◆ Concept Similar to AILS Work In Progress, With Added Longitudinal Dependency
 - ◆ Provides Benefits for Airports with Parallel Runways Too Close for Independent Approaches
 - ◆ Significant Impact on Future Runway Architecture Decisions

Paired Approach - Key Features

- ◆ Electronic Flight Rules - Pilots Assume Separation Responsibility
 - ◆ 2 Independent Modes of Surveillance
 - ◆ Proper Displays, Procedures, Training

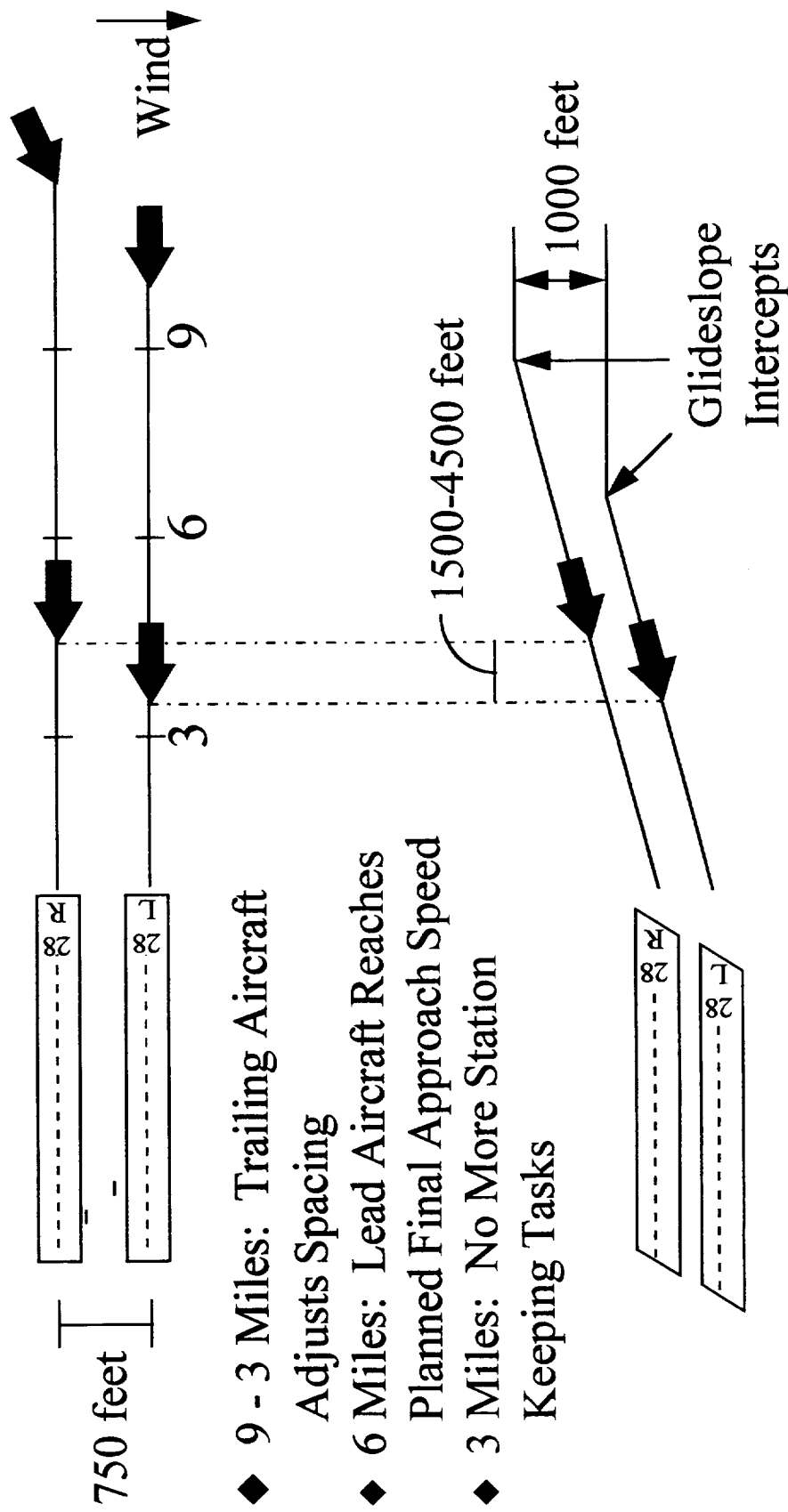
Paired Approach - Key Features

- ◆ Traffic Sequenced to Approximately Correct Spacing on Final With 1,000 Feet Altitude Separation
- ◆ Trailing Aircraft Adjusts Spacing Before Reaching Final Approach Fix
- ◆ No Station Keeping Tasks After Final Approach Fix

Paired Approach - Key Features

- ◆ Trailing Aircraft Escape Maneuver
 - ◆ Spacing Out of Window
 - ◆ Blunder
- ◆ Dual IMC Go-Around Procedure
 - ◆ Trailing Aircraft May Continue If VMC and Lead Aircraft In Sight

Paired Approach - SFO Example



- ◆ 9 - 3 Miles: Trailing Aircraft Adjusts Spacing
- ◆ 6 Miles: Lead Aircraft Reaches Planned Final Approach Speed
- ◆ 3 Miles: No More Station Keeping Tasks

Technology Needs

- ◆ Two Independent Modes of Surveillance
 - ◆ Passive ADS-B Reception
 - ◆ Active TCAS Interrogations

Interface Requirements

- ◆ Designation of “Paired Approach RW28L - Lead” or “Paired Approach RW28R - Trail”
- ◆ Designation of “Paired” Traffic
- ◆ Entry of Planned Final Approach Speed
 - ◆ Cross Linked to “Paired” Traffic

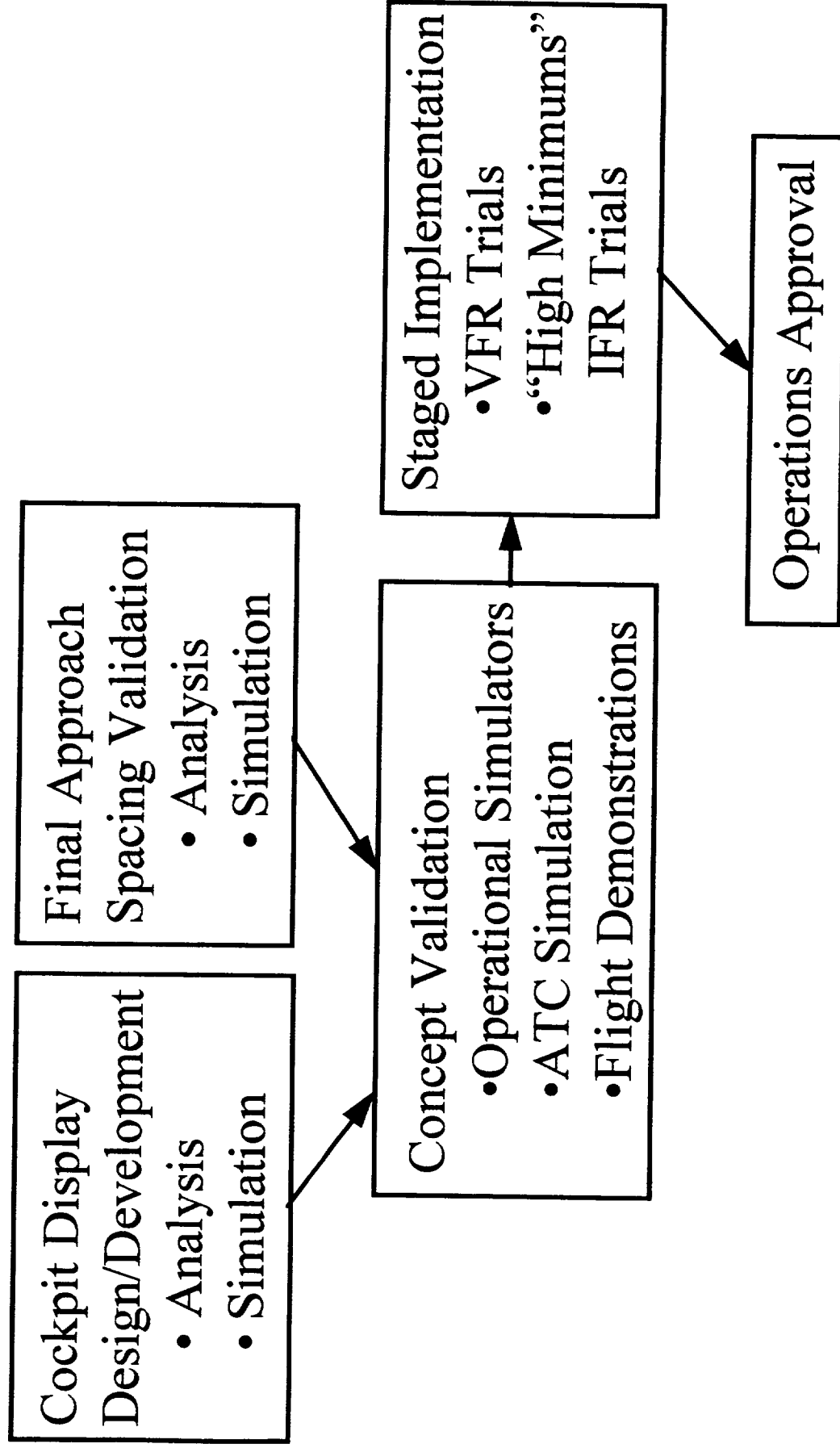
Cockpit Display Requirements

- ◆ Traffic Display With:
 - ◆ 1 or 2 nm Minimum Display Range
 - ◆ Flight ID
 - ◆ Graphical Indication of Range/Closure
 - ◆ Alphanumeric Range/Closure
 - ◆ Traffic Vector
 - ◆ Relative Closure Vector
 - ◆ Desired Relative Position at Final Approach Fix

Flight Director Requirements

- ◆ Target Airspeed
 - ◆ Lead Aircraft - Specified Deceleration Rate to Achieve Final Approach Speed by 6 nm
 - ◆ Trailing Aircraft - Computed Speed to Reach Desired Relative Position at Final Approach Fix

Implementation Milestones



Next Steps

- ◆ Expand Analysis/Simulation of Dependent Approaches
- ◆ Continue Development of Independent Parallel Approaches

Paired Approach Concept

Increasing IFR Capacity to Closely Spaced Parallel Runways.

Rocky Stone, United Airlines

This application envisions using active Traffic Alert and Collision Avoidance System (TCAS) interrogations and passive Automatic Dependent Surveillance-Broadcast (ADS-B) surveillance to maintain a dual runway approach capability to airports with closely spaced parallel runways that would otherwise revert to a single runway approach capability during low ceiling and visibility weather conditions.

It is proposed that two independent methods of surveillance be used since separation between the aircraft will be assured by electronic means, not visual contact. This will be an approach conducted under "Electronic Flight Rules (EFR)".

The goal is to develop a procedure that increases arrival capacity and also improves the level of safety over that associated with closely spaced visual approaches in use today.

Detailed Application Description:

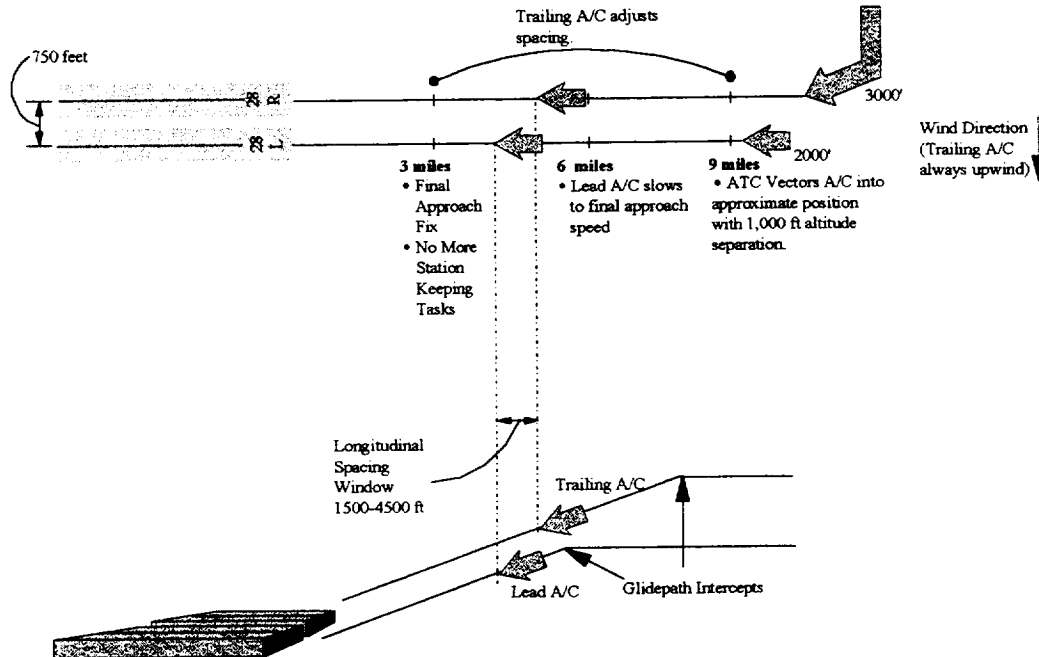
Each runway pair where this procedure is to be utilized needs to be surveyed to determine what spacing criteria is appropriate for the specific runway pair. For this example, runways 28L and 28R at San Francisco are used. These runways are spaced 750 feet apart. Both runways have ILS approaches. In this example, it is assumed that parallel GPS approaches are used, so that the divergence of the ILS localizer beam is not a factor.

A desired longitudinal aircraft spacing needs to be defined for this runway pair. A minimum spacing of 0.25 nm is desired to provide adequate time for the trailing aircraft to perform an escape maneuver, in the event the lead aircraft blunders into its flight path. A maximum spacing of 0.75 nm is desired for two reasons. First is to avoid wake turbulence in the worst case no wind scenario. It is assumed that if there is a crosswind, the trailing aircraft is always placed on the upwind side, to assist in avoiding wake turbulence. The second reason for the 0.75 nm spacing is to ensure that the aircraft land as a "pair" so that departing aircraft can leave from a crossing runway between arriving aircraft pairs.

Once the final approach spacing requirement is established, then how do aircraft get to that point in relation to another aircraft? It is proposed that the ground be responsible for assigning aircraft pairs and vectoring the aircraft onto final approach with 1,000 feet altitude separation into the approximately correct longitudinal spacing. The Converging Runway Display Aid (CRDA) now in use by the FAA could be reprogrammed to assist controllers in precisely vectoring aircraft into the approximately correct position on final approach. The lead aircraft is always vectored onto the approach on the downwind side of the trailing aircraft.

PAIRED APPROACH

SFO Example



Aircraft pairs need to be identified and assigned early enough for the aircraft to exchange an addressed data link message. The lead aircraft needs to enter its planned final approach speed so that it can be cross-linked to the trailing aircraft.

The lead aircraft's planned final approach speed is required by the trailing aircraft, so that it can position itself to remain within the longitudinal spacing window while on final approach. All station keeping maneuvering needs to be completed before reaching the final approach fix. The trailing aircraft needs to notify ATC if its planned final approach speed is not compatible with the "paired" lead aircraft.

Once cleared for the approach, the trailing aircraft becomes responsible for separation with the lead aircraft on final approach. Before reaching the final approach point, the trailing aircraft adjusts spacing so that it will remain within the 0.25 to 0.75 nm window the entire time while on final approach. For example, if the trailing aircraft is planning to fly final faster than the lead aircraft, it would set-up spacing to be near the 0.75 miles in trail when passing the final approach fix, as it would be drifting closer to the lead aircraft during the final approach segment. Conversely, if the trailing aircraft is planning to fly final slower than the lead aircraft, it would set-up to be near 0.25 miles in trail when passing the final approach fix, as it would be drifting further back during the final approach segment.

To minimize the impact on pilot workload, there is no station keeping task while on final approach. If the spacing moves out of the 0.25 to 0.75 nm acceptable range, the trailing aircraft executes an escape maneuver.

Since there is a potential of both aircraft going around with less than normal instrument flight rule (IFR) spacing, go-around/escape maneuver procedures need to be designed to maintain separation. If the lead aircraft executes a go-around, it needs to send an addressed air-to-air data link message to the trailing aircraft. This message should be automatically and immediately sent when the pilot initiates a go-around. It is proposed that the lead aircraft be limited to 2,000 feet per minute climb when initiating a go-around. This will allow the trailing aircraft to execute a maximum rate of climb go-around, to always remain above the flight path of the lead aircraft. The trailing aircraft go-around procedure and/or escape maneuver is specified to level off 1,000 feet above the lead aircraft's go-around altitude, so that ATC can resume normal IFR separation. If in VMC, and the lead aircraft is in sight, the trailing aircraft may continue the approach if the lead aircraft executes a go-around.

Air Traffic Control (ATC) responsibilities:

1. Pair up properly equipped and qualified aircraft. Advise aircraft of their "partners" early enough for the trailing aircraft to obtain a data link message from the lead aircraft containing their planned final approach speed.
2. Provide sequencing to the runway. Place the lead aircraft on the downwind approach from the trailing aircraft. Vector the trailing aircraft within 0.25 and 0.75 miles in-trail of the lead aircraft, with the trailing aircraft 1,000 feet above the lead aircraft.
3. After clearing the aircraft for a paired approach, separation responsibility transfers to the trailing aircraft. ATC maintains separation responsibility for both aircraft with any other traffic.

Lead Aircraft - Pilot Responsibilities:

1. Enter planned final approach speed, so it can be data linked to the trailing aircraft for planning purposes.
2. When cleared for the approach, maintain 170 KIAS until reaching the designated slow down point. Decelerate to planned final approach speed (or slightly higher if necessary) at a defined deceleration rate.
3. If a go-around is necessary, fly the published go-around procedure with a maximum 2,000 feet per minute climb rate.

Trailing Aircraft - Pilot Responsibilities:

1. Advise ATC if the final approach speed of the lead aircraft is incompatible with being able to perform this procedure.
2. After vectored into position and cleared by ATC, use speed as necessary to adjust the spacing so that after the final approach point, spacing will be maintained by the anticipated drift due to differences in final approach speeds.
3. Execute an escape maneuver if the lead aircraft blunders into trailing aircraft flight path.
4. Execute an escape maneuver if the spacing on final approach moves out of the established range.
5. Execute a maximum rate of climb go-around if the lead aircraft executes a go-around.

AILS Single Aircraft Flight Test of November 1996

Charles Scanlon
NASA Langley Research Center



NASA Langley Research Center Boeing-737

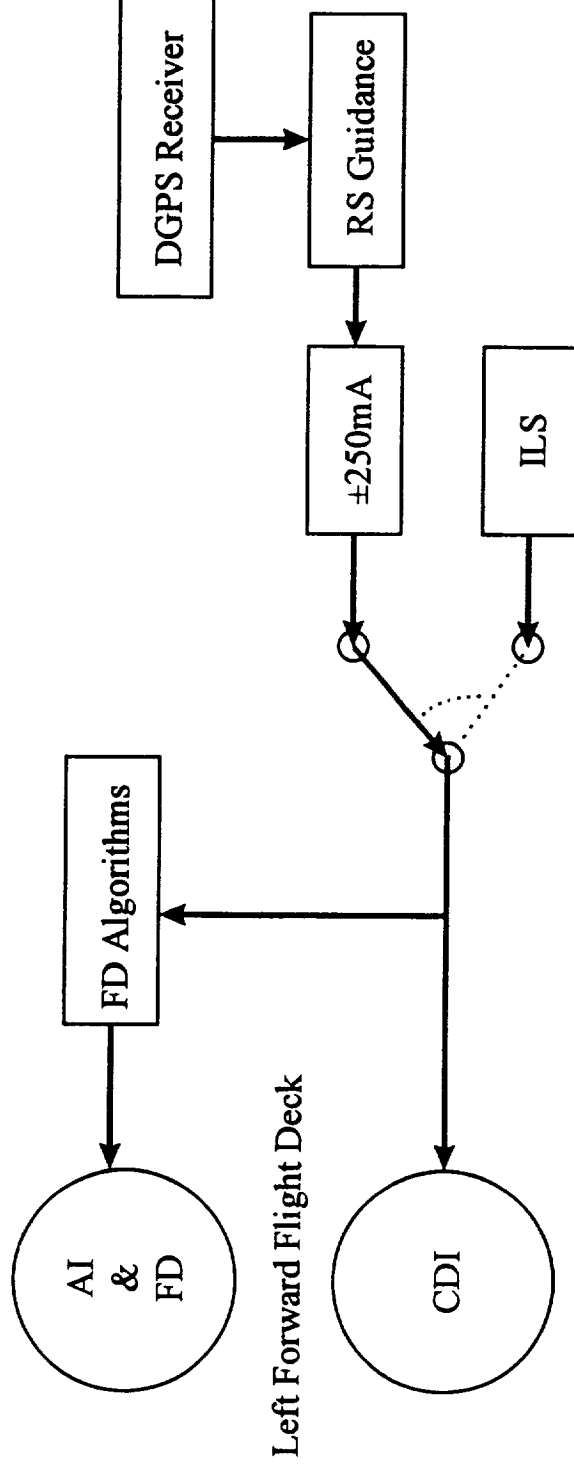
Basic Objective

Validate precision navigation, attitude, and track data obtained in simulations.

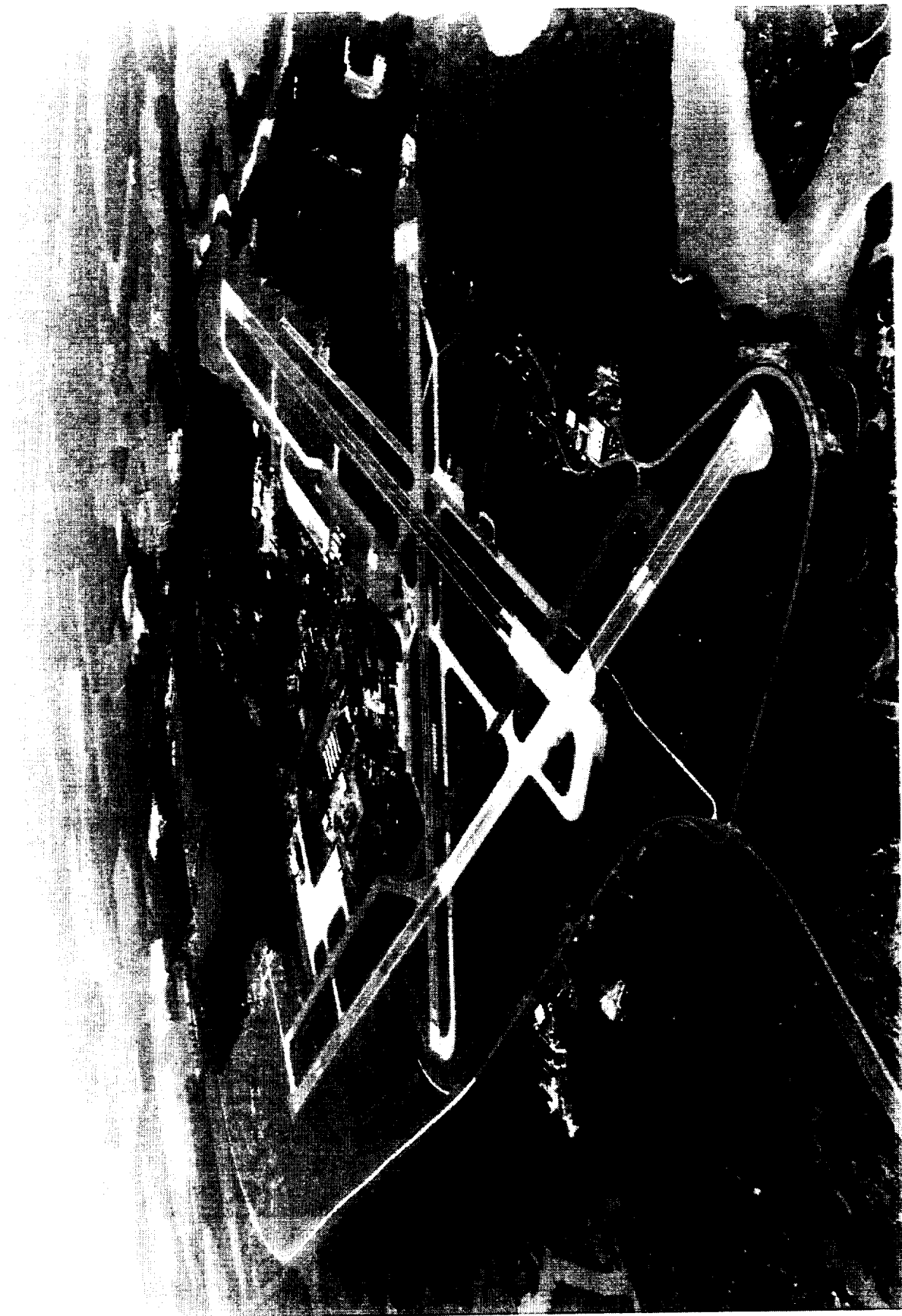
Flight Test Questions

- Can the “Rocket Ship” approach geometry be easily hand flown in adverse wind conditions?
- In adverse wind conditions, would the alert algorithm be too sensitive? (i.e. set off too many false alerts.)
- Do the flight characteristics of the airplane closely match the characteristics of the simulator during the emergency escape maneuver?

B737 Modifications



Left Forward Flight Deck



NASA Wallops Flight Facility

Test Matrix

- Two Windy Days (15kt+)
- Approaches to all six runways at Wallops
- Six “Emergency Escapes” at 6000’ AGL

AILS Two Aircraft Flight Test of Fall, 1998

Charles Scanlon
NASA Langley Research Center

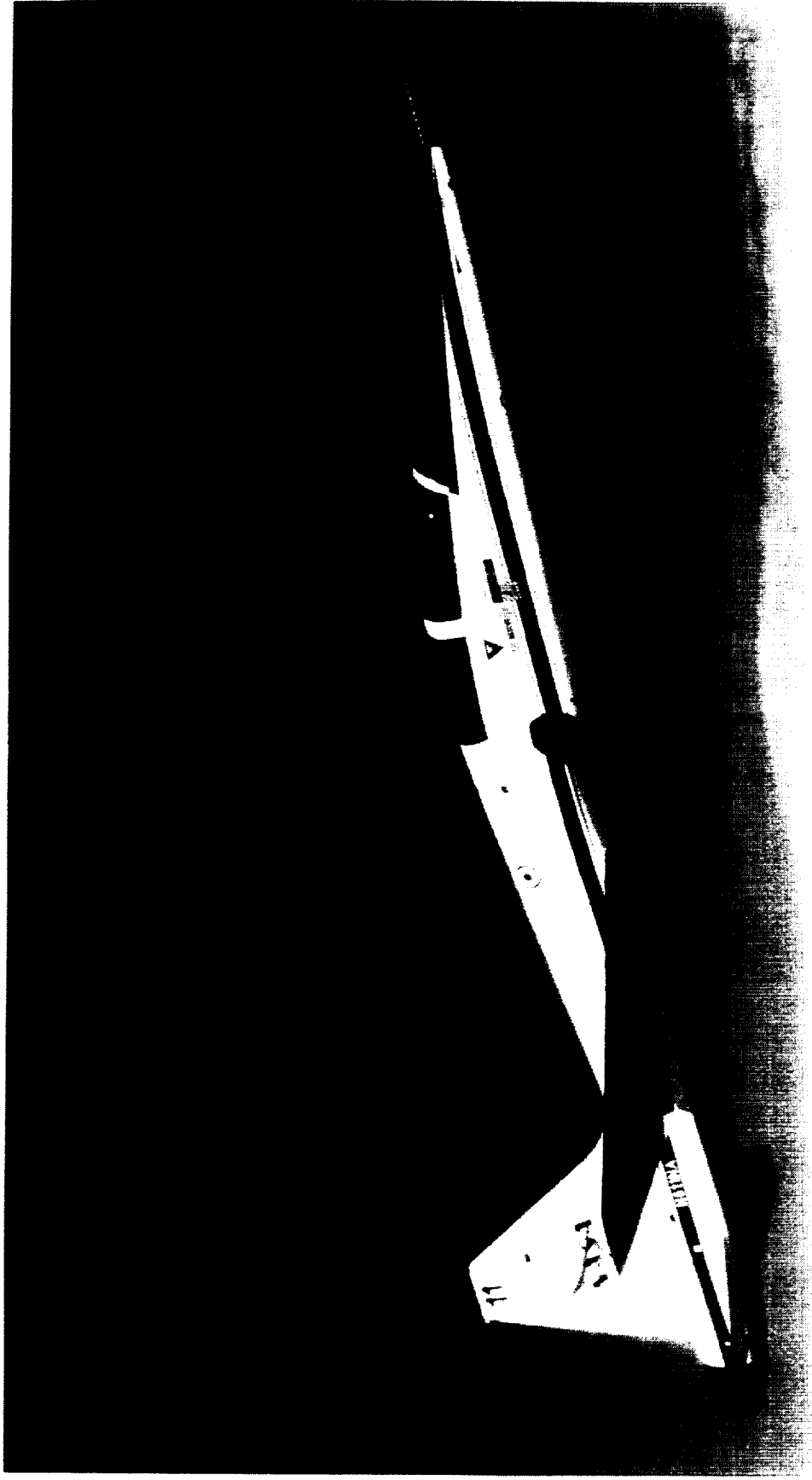
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Objective

Validate ALLS simulation data in actual flight conditions using two aircraft, one as the “Evader” flown by an outside guest pilot and the second as the “Intruder” flown by a NASA test pilot.



NASA Langley Research Center Boeing-757



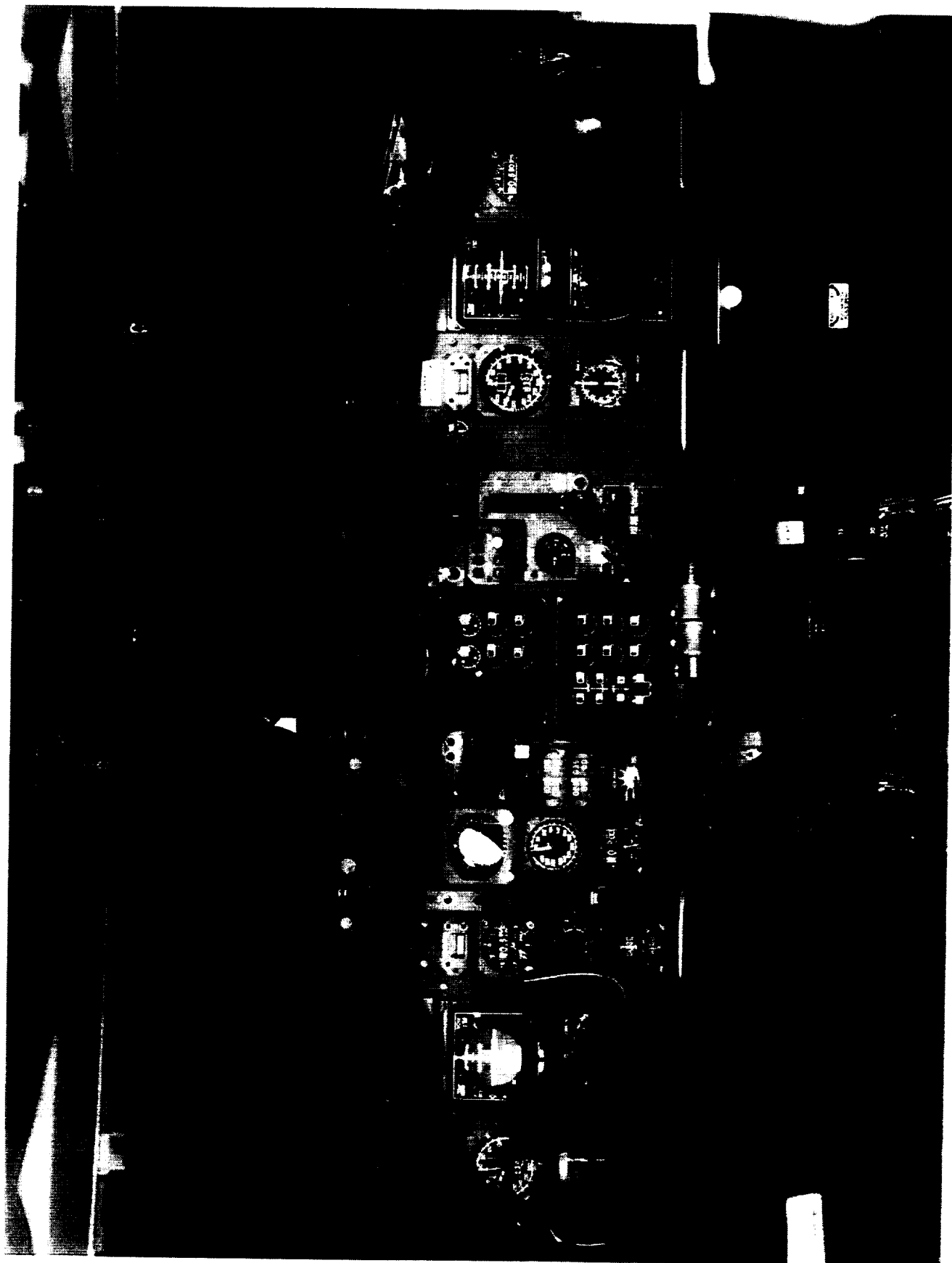
NASA Langley Research Center T-38

Aircraft Modifications

(B757 & “Intruder”)

- AILS displays and alerts programmed in the B757
- ADS-B system installed in B757 for reception of packets from “Intruder”
- ADS-B system installed in “Intruder” for transmission of packets.

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NASA B-757 Cockpit


Plan of Test

Program aircraft and simulator with AILS alerts and pilot interface

Approaches to imaginary parallel runways 5000' above NASA Wallops will be programmed

Eight outside airline subject pilots will be trained in the simulator in the morning and inflight test approaches will be conducted in the afternoon (in VMC)

The “Intruder” aircraft will be an aerobatic NASA aircraft flown by NASA test pilots



Overview of Precision Runway Monitor (PRM) Program

Gene A. Wong
PRM Product Lead, AND-450

October 29, 1996

High-Update Surveillance System

Characteristics:

Surveillance accuracy higher than current airport surveillance radars

- Azimuth accuracy of 1 milliradian (60' @ 10 miles)

Update rate of approximately once per second

High resolution color ATC display with automated alerts for aircraft deviation

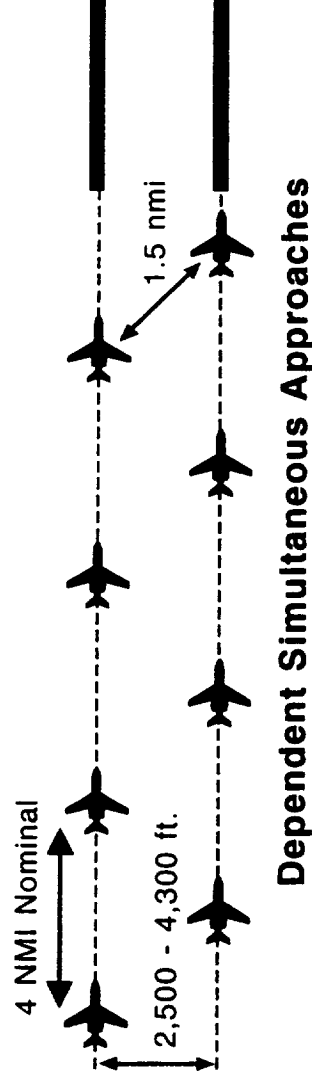
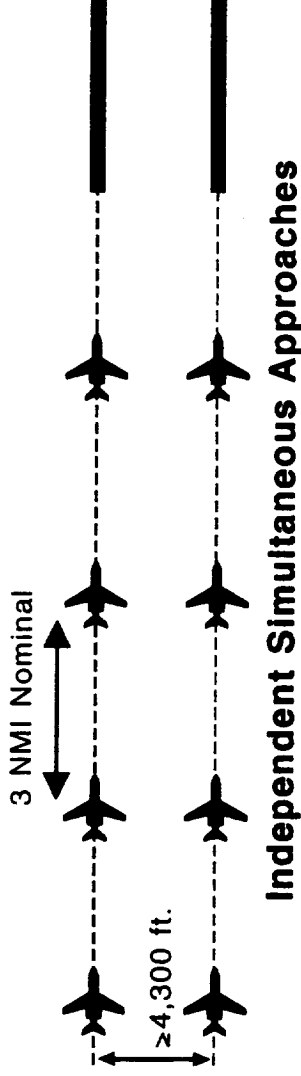
PRM available now; low-cost alternatives in future

System Objective



Provide the capability to conduct simultaneous independent instrument approaches to parallel runways spaced less than 4300 feet apart.

Multiple Parallels (Including triple runways)



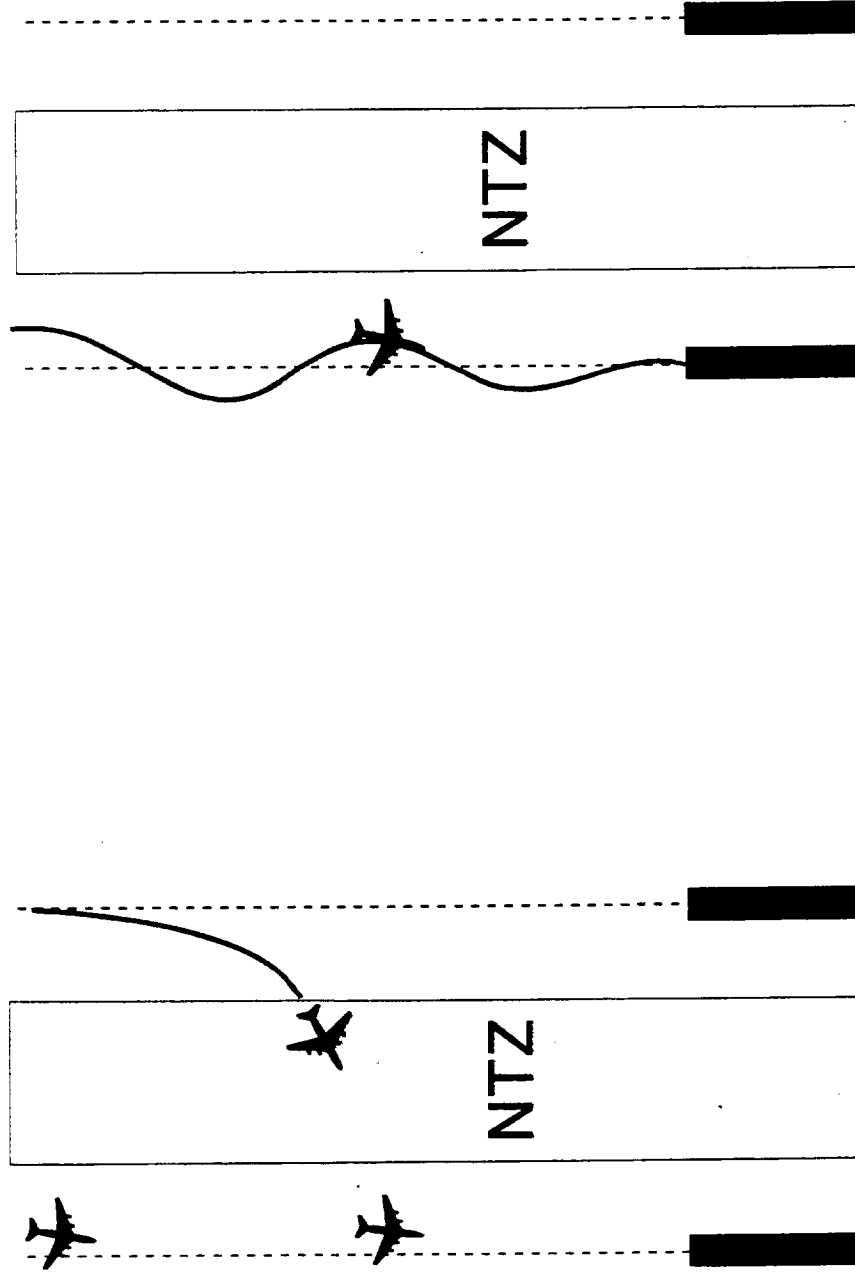
Independent approaches can yield up to 40% more landings than dependent approaches in high-density traffic and IMC

Factors Affecting Closely Spaced Parallel Approaches

Approaches

Pilot/Aircraft Navigation

Performance



Methodology for Procedure Development

Human-in-the-loop realtime simulation using:

- Controllers and line pilots
- ATC displays
- Certified flight simulators remotely connected to
FAATC

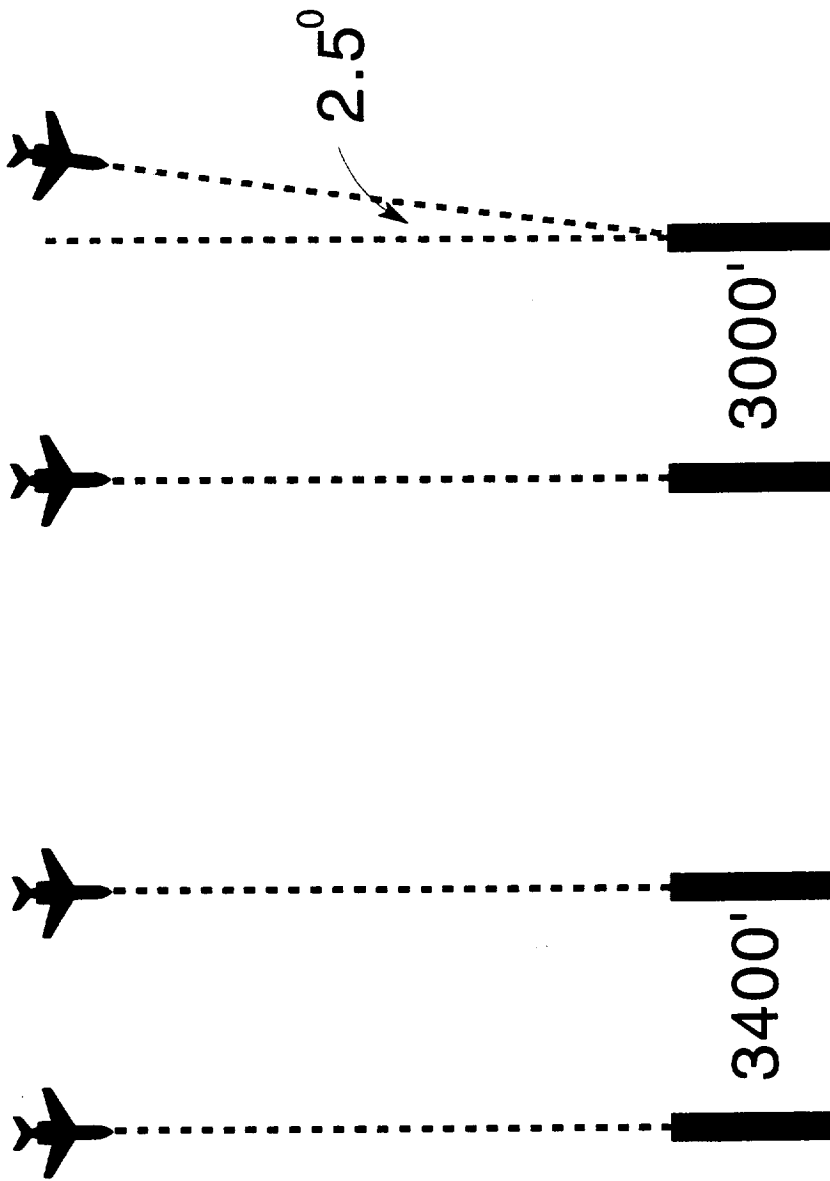
Collision risk model and safety analysis

Data collection

Operational evaluation by FAA Technical Work
group

Approved/Recommended Procedures based on High-Update Surveillance System

Dual:

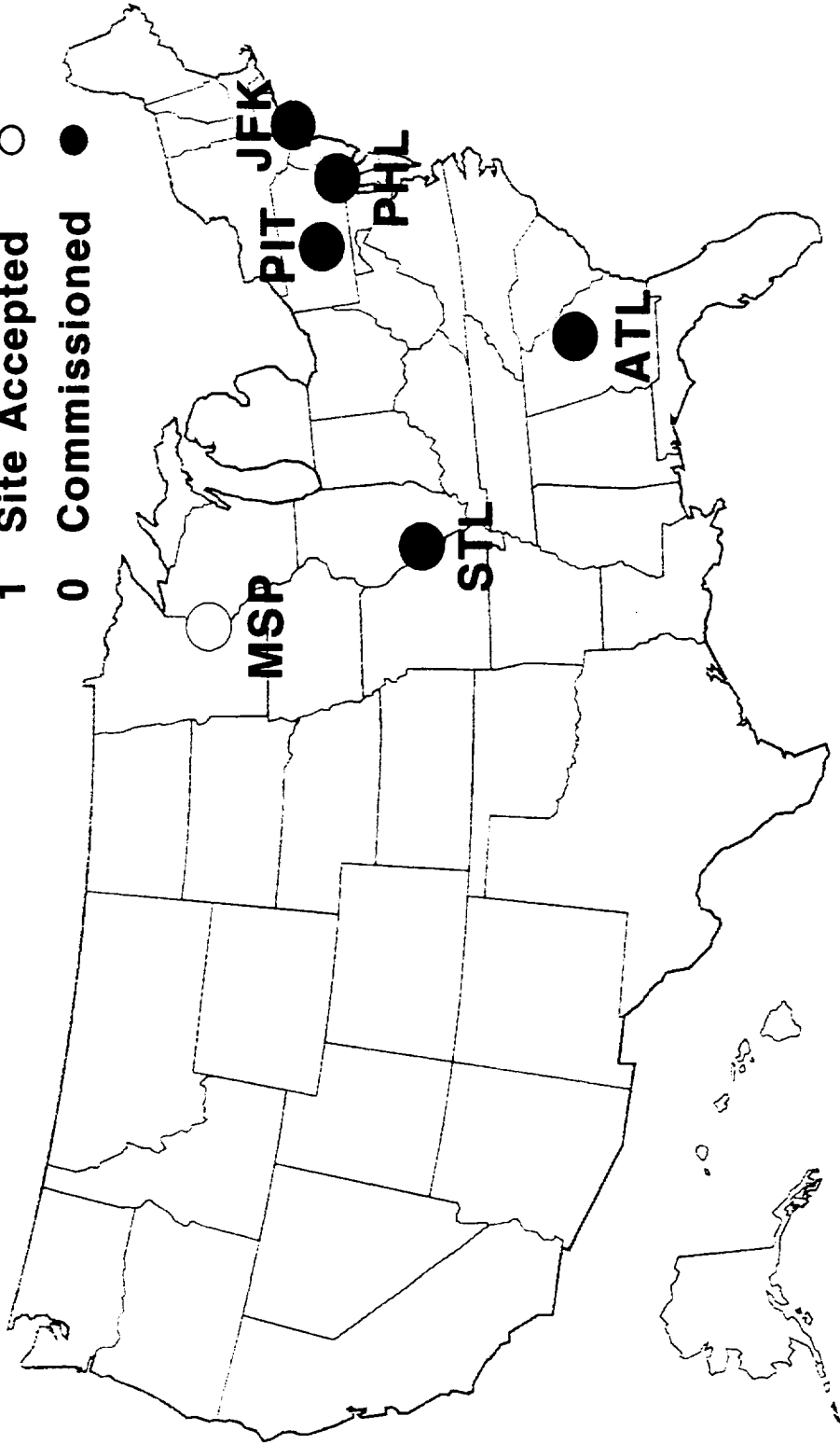


Triple: ATL/PIT procedure for simultaneous ILS approaches
recommended

PRM Status



- 1 Delivered ●
- 4 To Be Delivered ●
- 1 Site Accepted ○
- 0 Commissioned ●



Final Sensor Delivery to ATL or PIT

PRM Commissioning/Installations

1996	1997	1998	1999	2000	2001
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MSP



JFK



STL



PHL



ATL/PIT



Site Acceptance



Commissioning



PRM Issues



Pilot Issues reduced to 1: Pilot Training

- Consensus: Awareness and procedure training via video tape and written material is necessary to improve breakout performance
- Whether additional hands-on flight simulator training is needed for breakouts

Resolution of Local Issues

JFK - Airspace

STL - “Flyability” of modified procedure

Potential Future Low-Cost, Ground-Based Technologies

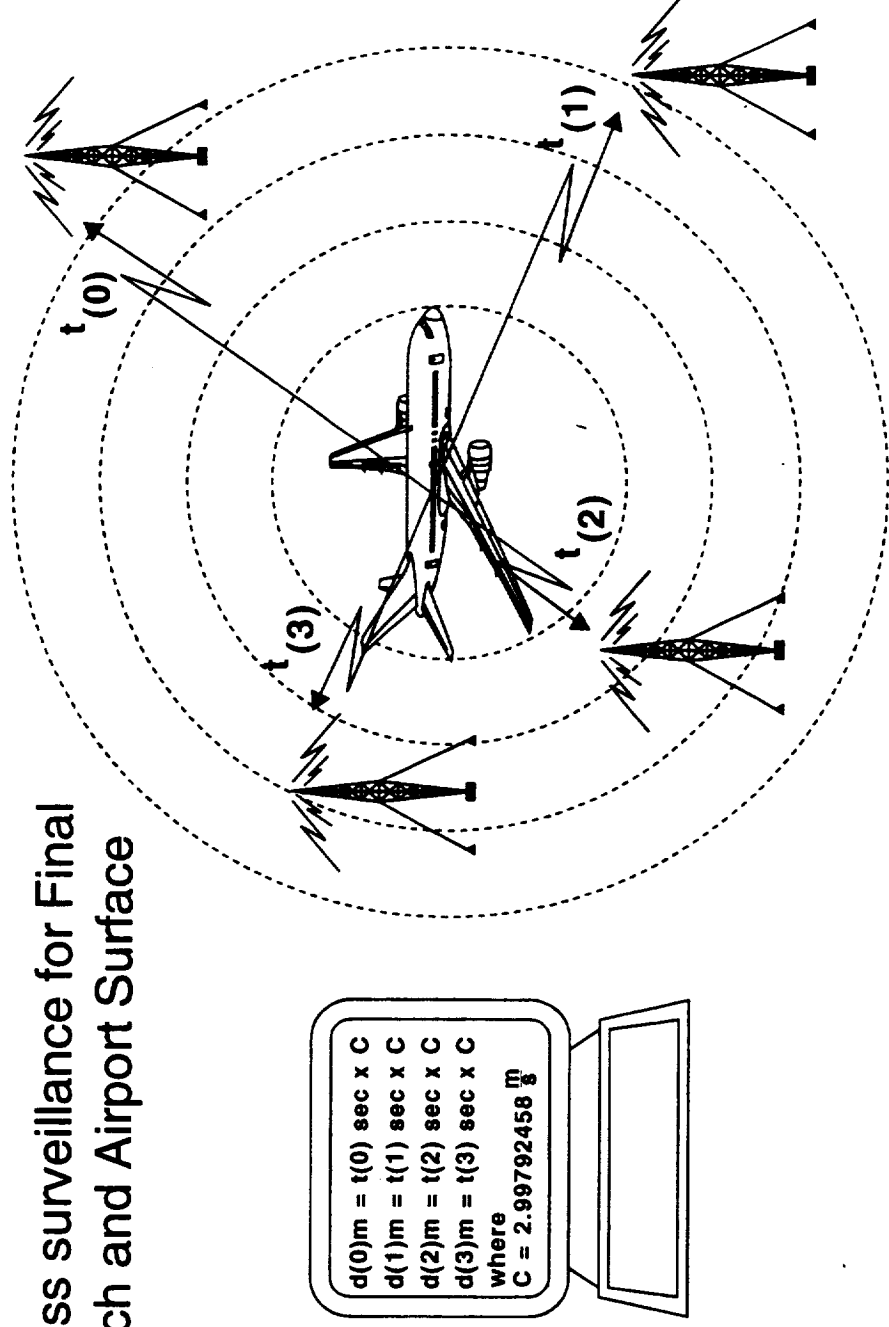
Multilateration based on a network of low-cost receivers/transmitters (R/Ts) for deriving aircraft positions

- Atlanta demo in late 1996

Automatic Dependent Surveillance/GPS downlinking positions to ground ATC computers (STARS) for monitoring

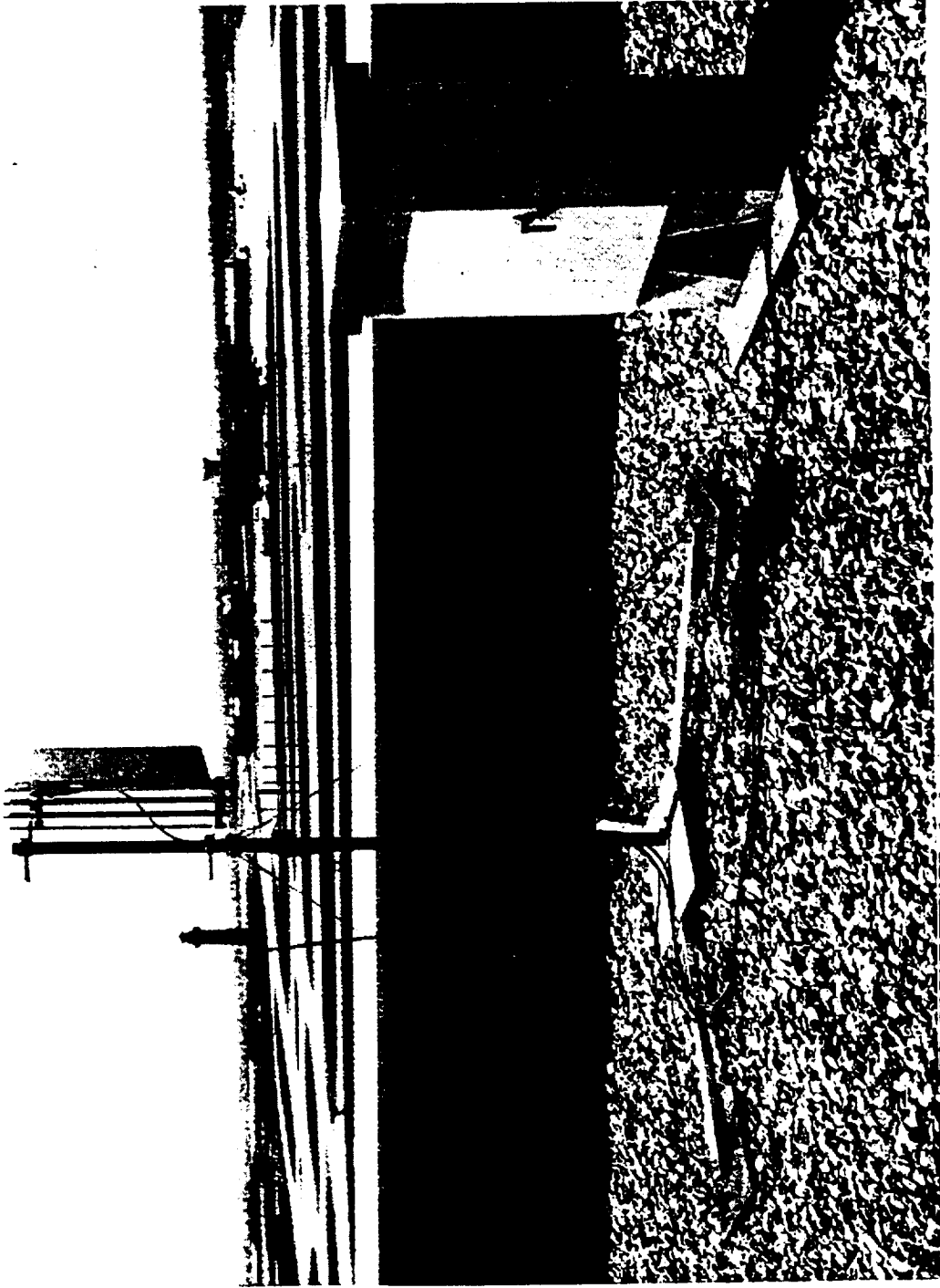
Potential Technology - Multilateration

- Uses four or more ground R/Ts to determine aircraft position
- Works with ATCRB transponders and Mode S
- Substantially lower cost than PRM
- Seamless surveillance for Final Approach and Airport Surface



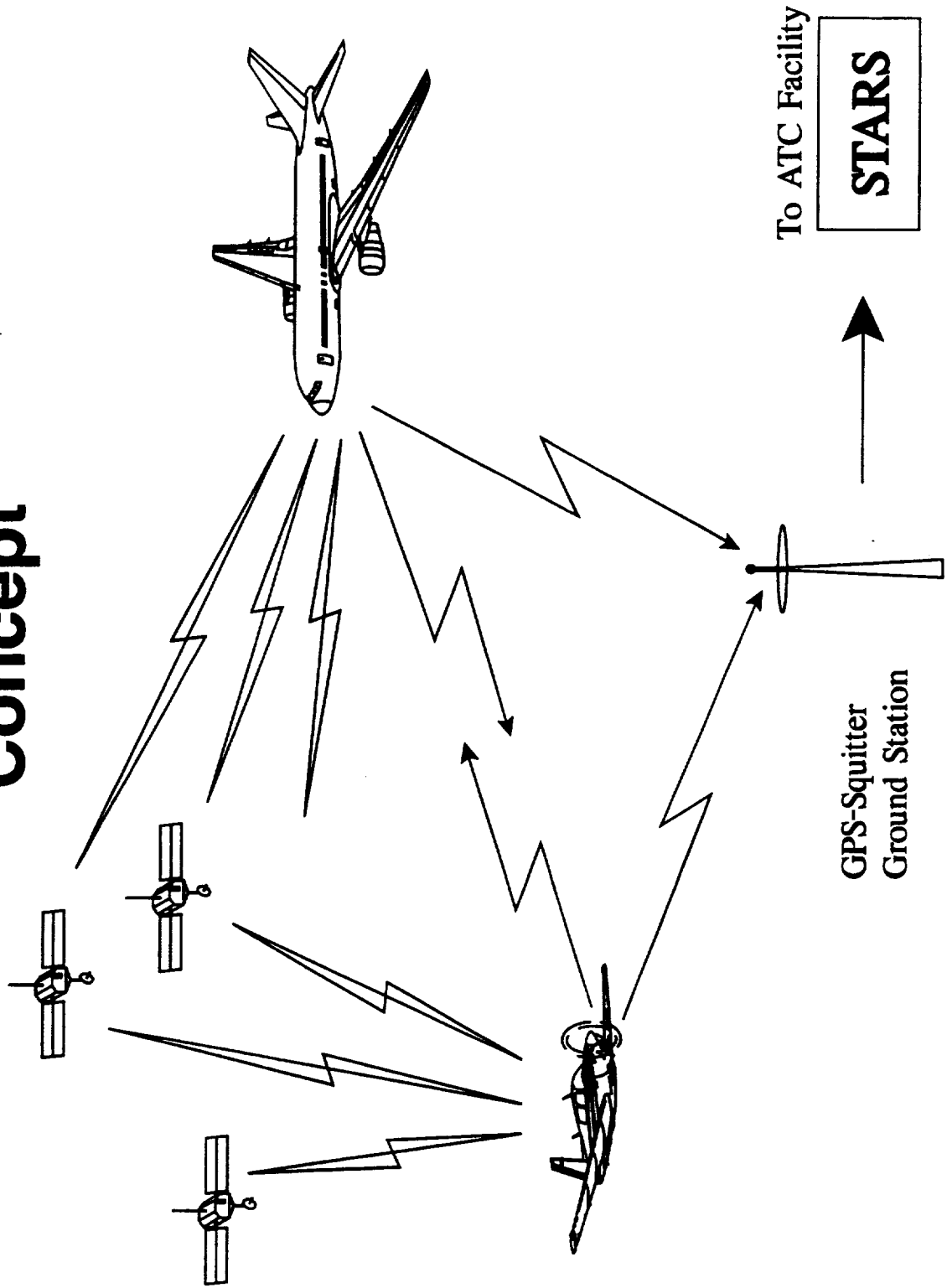
Potential Technology - Multilaturation

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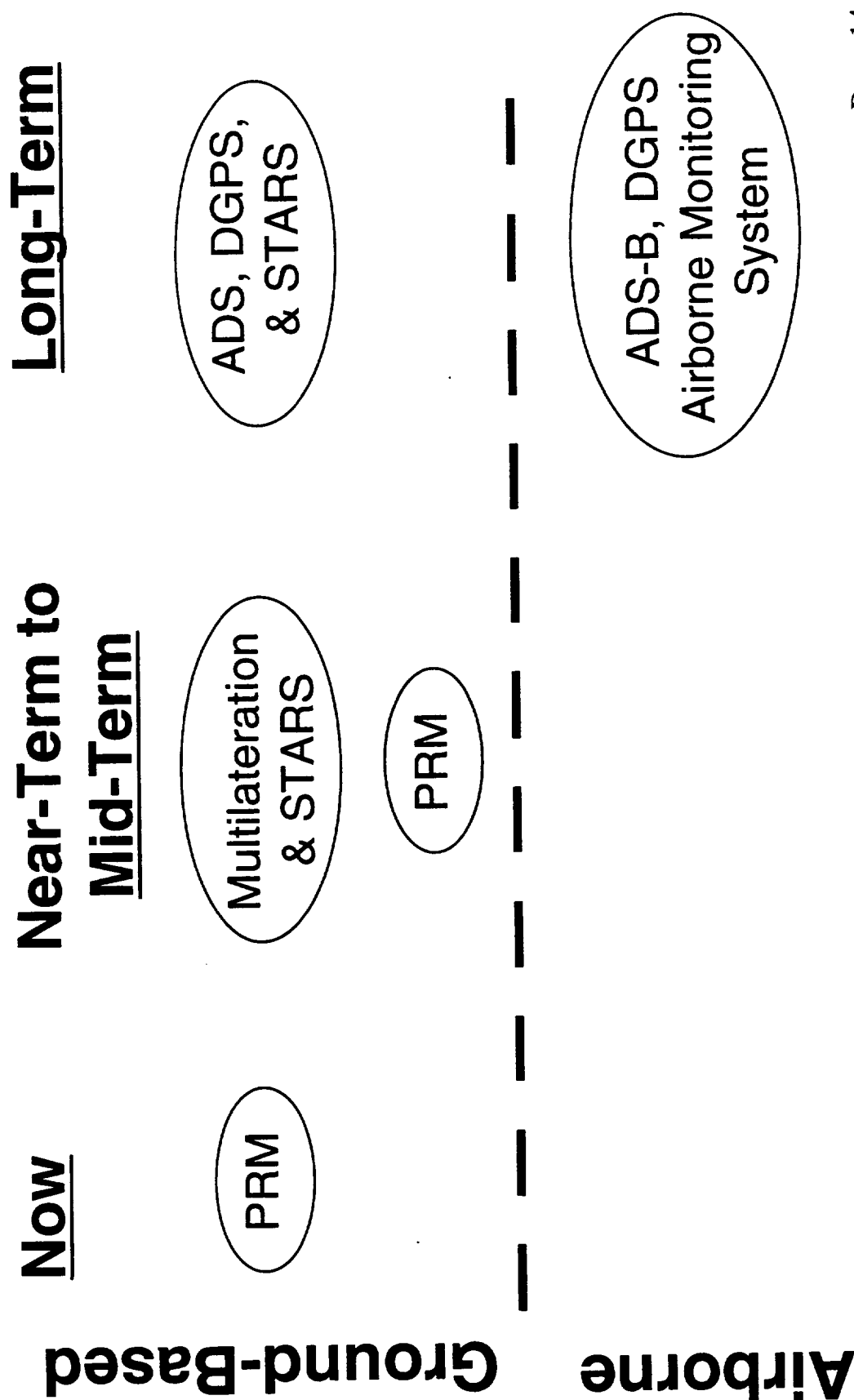


Automatic Dependent Surveillance/Geo

Concept



Vision of System Evolution



ADS-B Standards

**Rocky Stone
United Airlines**

**NASA Langley
Parallel Runway Workshop
10/29/96**

RTCA SC-186 Activity

- ◆ Minimum Aviation System Performance Standards (MASPS)
- ◆ Generic Requirements, Not Specific to a Transmission Medium

ADS-B MASPS (Cont.)

- ◆ Operational Requirements Based on Projected Applications:
 - ◆ Free Flight (Conflict Probe)
 - ◆ Surveillance for Closely Space Parallel Approaches
 - ◆ Station Keeping (Enroute and Terminal Area)
 - ◆ In-Trail Climb/Descent

RTCA SC-186 Activity

- ◆ Minimum Operational Performance Specifications (MOPS)
 - ◆ 1090MHz Extended Squitter ADS-B System
 - ◆ Cockpit Display of Traffic Information

Wake Vortex Systems

Application to AILS

David A. Hinton

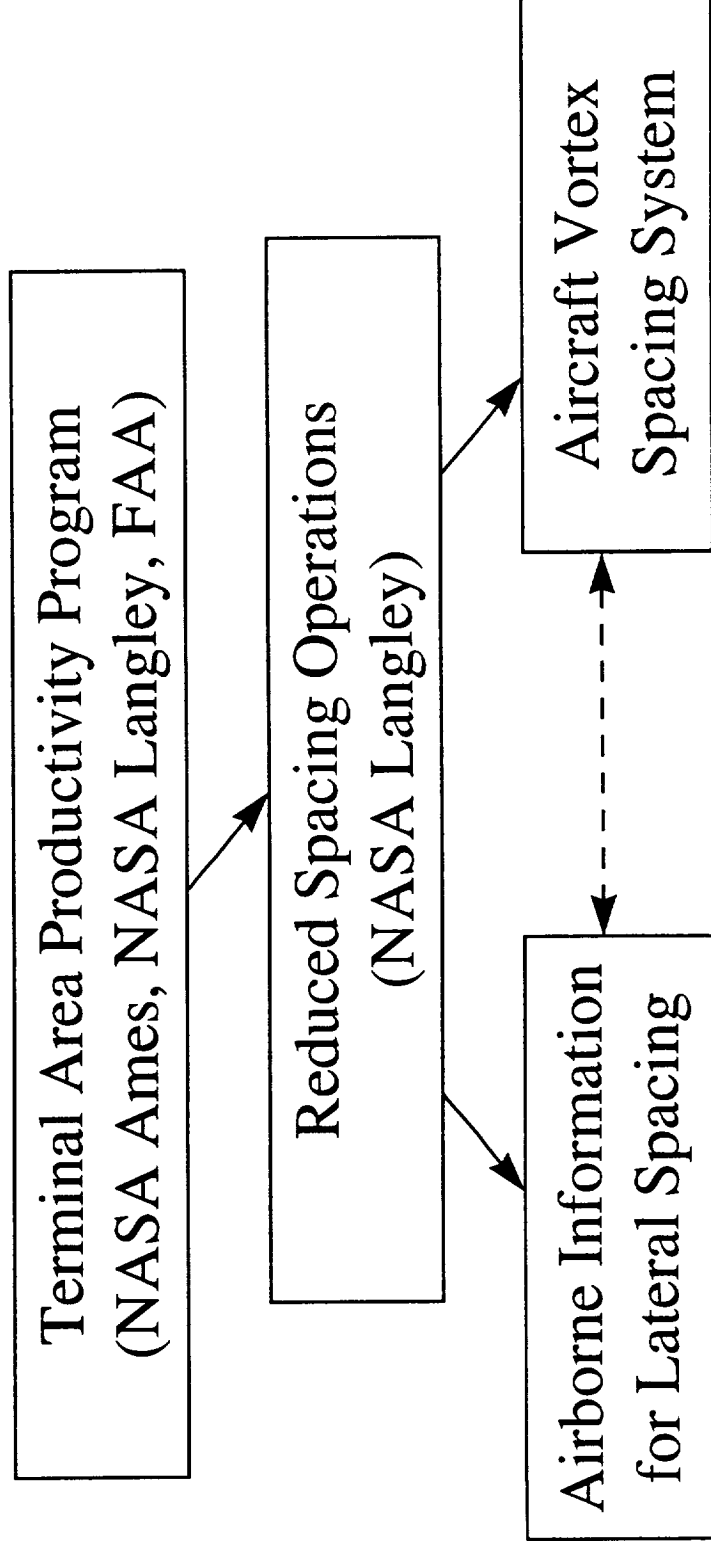
AILS Workshop

October 29, 1996

Wake Vortex Systems

Support of AILS

AILS development involves wake vortex considerations - which the AVOSS element can address.



Aircraft Vortex Spacing System

Goal

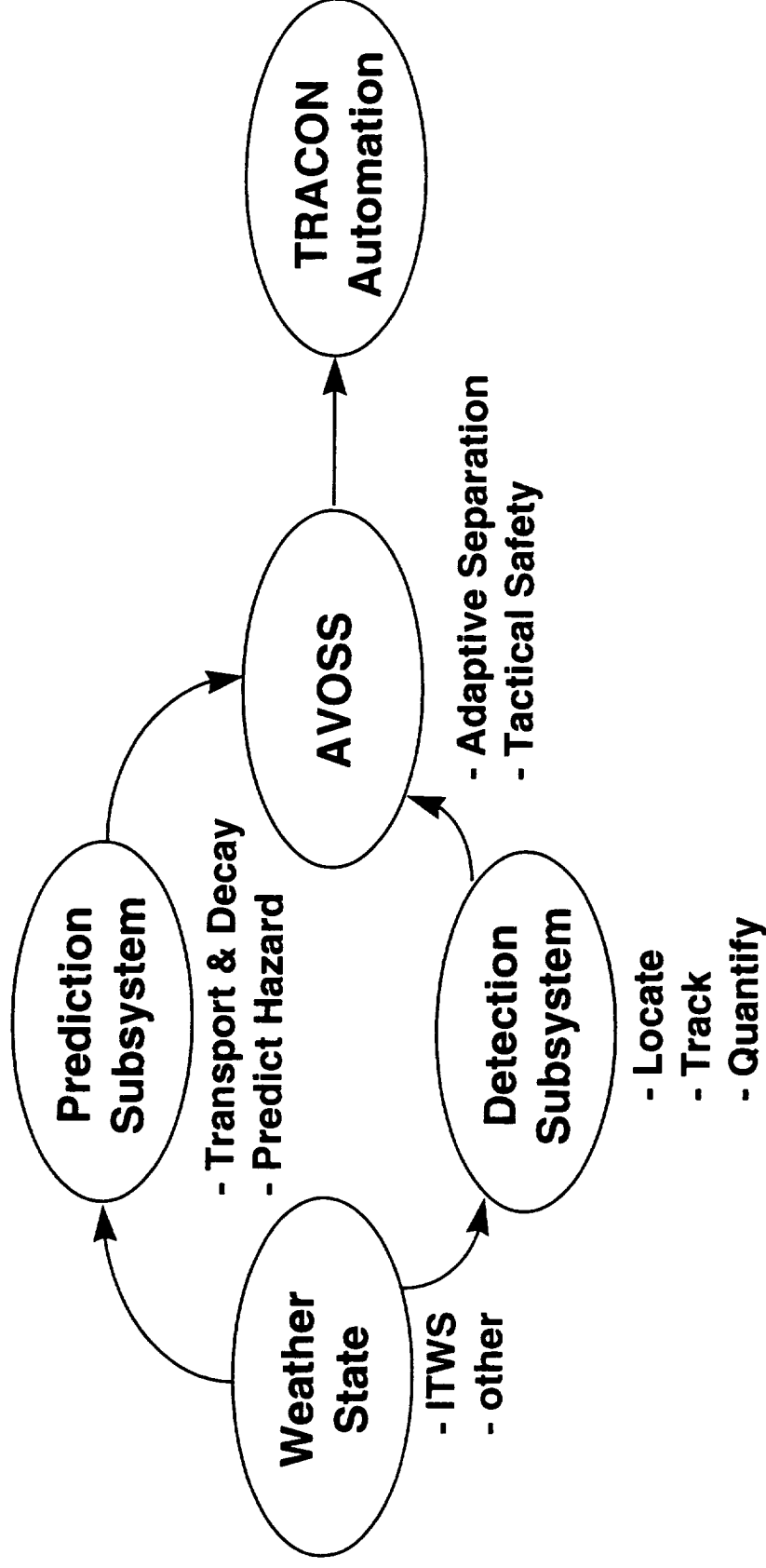
Provide dynamical aircraft wake vortex spacing criteria to automated ATC systems at capacity limited facilities with required lead time and stability for use in establishing aircraft arrival scheduling. Support TAP goal of improving instrument operations capacity to current visual operations level.

AVOSS System Concept

- Separate aircraft from encounters with wake vortices of an operationally unacceptable strength.
-
- Define protected corridor from outer marker to runway and predict time for vortex to clear. (“Transport Time”)
 - Define operationally unacceptable wake strength and predict time to decay. (“Decay Time”)
 - Combine and provide to ATC automation. (“Residence Time”)
 - Monitor safety and provide predictor feedback with wake vortex detection subsystem.

Aircraft Vortex Spacing

System Architecture



Available AVOSS Program Tools

- Enhanced weather systems:
 - Profile winds in the entire approach corridor.
 - Nowcasting.
 - Integrated Terminal Weather System (ITWS) coordination.
- Validated numeric wake simulation tools:
 - Meteorological framework.
 - Validation against field data.
 - Follows technical approach applied to highly successful Wind Shear program.

AVOSS Program Tools

- Wake Vortex Sensor Development:
 - MIT Lincoln CW lidar with automated wake acquisition and tracking capability.
 - NASA pulsed lidar development.
 - Other technologies under investigation.
- Program integration:
 - ATC procedural aspects.
 - Controller Human Factors (@NASA Ames).
 - Field demonstration infrastructure.

AVOSS Plans/Schedule

- Initial field studies and numeric wake simulation 2-D version completed.
- 3-D numeric wake and planetary boundary layer simulation in development.
- Wake sensitivity studies and initial AVOSS prototype design underway. Includes atmospheric profiling capability and weather/lidar/prediction system integration.
- Dallas-Fort Worth Int'l Airport being instrumented for the AVOSS prototype tests. Includes dedicated weather sensors, ITWS tie-in, ATC radar data tie-in, and wake sensors data link.
- AVOSS testing and development to follow incremental stages through year 2000 TAP demonstration.

Potential AVOSS/AILS

Coordination

- Wake considerations in blunder situation.
 - Implications for alerting criteria.
- Wake considerations in normal operations.
 - Map possible lateral drift distances vs. wake strength.
 - Identify subset of atmospheric profiles that can transport a hazardous wake to a parallel approach, at different path separations.
 - Provide AVOSS weather system outputs to support TRACON decision processes.

Summary

- AVOSS development effort brings skills and infrastructure to address wake concerns for AILS.
- At first stages of dialogue, coordination, and issues identification.

Transcript of the Wrap-up Session

This section presents minutes of the discussions during the wrap-up session of the workshop. The manuscript was prepared from a taped recording. In some cases there was difficulty in understanding the audio recordings or the name of the speaker may have not been recorded. Every effort has been made to capture the statements of the speakers as accurately as possible. We apologize for any statements that may have been misinterpreted. We have indicated some of the unclear recording segments with "...".

Brad Perry (Moderator - NASA Langley Research Center, RSO Manager)

In our last session, this is to be a wrap-up session involving all of the speakers who have presented today. Additionally, I'd like to introduce Leonard Credeur. Leonard is the Deputy Manager for RSO. As such, he has keen insight into many of the technical aspects of the key areas that have to be addressed in implementing an AILS application. I would like to have Leonard join the other speakers.

This is intended to be an open format. This will provide an opportunity for you to ask those questions we just didn't have time for during the day. We can also talk about some of the fundamental issues to be solved.

Remember, I had a chart this morning that listed several of the key issue areas that have to be addressed in implementing an AILS-type technology. Bob Jacobsen showed a chart in his presentation defining the role of both NASA, as well as the FAA, and others in implementing the technology. The key point of his chart was that we are somewhere between concept exploration and concept demonstration now. Obviously, there are many other steps that have to occur to get to operational reality. You'll recall that I had yet another chart in my presentation where I talked about some of the keen interest that has been shown in AILS to date. There are airports with existing problems. There are airports planning new construction which can benefit from this kind of technology. But, overall, for this technology to come together properly, it is going to take all the right partnerships working to make it happen. Specifically, the technology capability has got to be there. We are going to continue working the NASA research to that end. It will require avionics manufacturers to build the equipment, it's going to require airlines to buy the equipment. As Rocky Stone pointed out, they're only going to buy the equipment if it's cost effective. It's going to be used at specific airports. Obviously, the airframers -- Boeing, McDonnell-Douglas, and other major players -- will be involved at an appropriate point. A crucial role will be up to the FAA to pave the way through the certification and operational status process that's required.

We'd like to explore everyone's thoughts between now and about five o'clock. To that end let's go ahead and start. We have a roving microphone. Please ask your questions over the microphone. We are going to be recording the questions as well as the responses to these questions.

To that end, I'd like to open the questioning from the floor.

Jack Wojciech (FAA, Office of System Safety)

We had heard earlier, and I've been reading, and I know from some of my background that approximately 50 to 60 percent of the TCAS RA's are not being followed and I am concerned a little bit that if we're in this tighter situation, and we have a similar reluctance (Someone had mentioned every second represents one hundred twenty-five feet). In your part task you are getting responses. In some cases they may not respond. The same things, the same stress are not a part of the AILS, or this type system. But I do believe we need to have a kind of a backup for that or it needs to be considered in the risk assessment. That was my question.

Perry: Okay, who would like to take that.

Trent Thrush: I'm not sure where you get your statistics and whether it has to do with traffic in visual conditions or in IMC conditions. I think that would have a big dependency. Maybe one of the reasons that pilots don't follow some RA's is that they see the traffic.

Wojciech: You say the conditions aren't present and I appreciate what you are saying. But there is still the need to understand the human factors involved. How would company policy play into that go around through something that people don't want to do? Of course they will do it if they know that it is safe, critical and vital, but I just think we need to be sure. We're in a little different ball game as we tighten up. Clearly it needs to be more evolutionary, just to understand that process. Even if we can do 1500 feet, we should never start at 1500 feet.

Credeur:

I think also, I agree with you that before this is operationally acceptable there probably is a lot of risk assessment that has to be done and I don't think we are there yet. Some more studies obviously have to be done, as well as some modeling and risk assessment kind of work.

Rocky Stone:

I absolutely agree with that. And I kind of look at it as the analogy that I think Charlie Scanlon brought up. This is something like an N1 cut. Where as TCAS RA's, I think the average airline crew averages one every other month or something like that. And they can, I hate to say this, they can become mundane or routine. Especially if you get that one every other month up in the same place and you know what's causing it. Where as, this hopefully will be at most a once in a life time situation although I don't have any V1 cut data at the top of my head, I can tell you just from our recent past experience, Charlie, that in real life we don't handle them very well. And that definitely has to go into the safety model.

Perry: Good point.

David Jacobs (North West Airlines)

I guess, on the FAA's question, that kind of pre-supposes the fact that we have simulator training for wind shear avoidance, we have simulator training for stall avoidance, so we probably ought to consider simulator training for this type of avoidance too. If we are going to talk about a once in a while type of event that's going to require immediate action, I don't think watching a video is going to be the answer. On that point. On the second point, we talked about earlier that PRM was introduced at Minneapolis. Our A320 group in particular had some concerns because their particular airplane, in the auto-coupled mode, does not come out of the auto-coupled mode to do this turning maneuver as quickly as the old Jurassic DC-9 that I fly where you hit a button and you're home free. So there is not a lot to turn off. But, going a little bit further with that discussion, the time to react is also based on not just the pilot but the airplane, and that can change. There is a variety of times in there that you can throw in there. And you don't want to equate that so much to like an RTO event that has a whole bunch of different factors related to it. It's an event you don't want to do and you want to shed responsibility or things that would cause you to do that RTO as you get closer to your V1 speed. In other words, at 80 knots a yellow light might cause you to do an RTO, but as you get close to V1 it had better be a red fire light or you're going to go. Because of the problems that were brought up that we usually don't do that very well and, if we're balanced field, we stand a great risk, depending on a lot of other factors, of not being able to stop the airplane. With regards to this maneuver, you've got pilot reaction time at the end of a 5-day leg on a red eye, in the middle of the night, a heavy aircraft on a turn back versus a light aircraft. The aircraft response gets into this equation too. So I think the important factor as Charlie and I talked about is what's the miss distance at the end of this whole maneuver.

And if your miss distance continues to be satisfactory, for where ever you want to put it at, then you are solving the reaction time with all of its factors. The miss distances are getting too close, then you can start breaking it down, I think to discuss, what's causing that. Is it because the pilots are slow to react and only see it once in a while? Is it the aircraft, or all of these other factors?

Perry: Comments.

Scanlon: That's a very interesting discussion. Especially the disconnect that a lot of us have been worrying about. And that's something that we definitely have to look into. If it is disconnect of the auto-throttle, ...that ... has added to some of the reactions times that the FAA has measured in their PRM ..., that's certainly something I intend to look into in much more detail as soon as I can. So, thanks for the comment. That was very good. The bottom line is the miss distance; I agree with that. The reaction time, we may have over stressed that a little bit. But I guess we were getting such different response times than what has been measured in the past. I wanted to make sure everybody understood exactly what they were and how we got them. And why we got such good numbers there. Thank you very much.

Richard Licata (Emery Airlines):

I fly a pre-Jurassic DC-8. And if you can get the aircraft to react in 5 seconds, you're good. All that aside, I just want to comment on the technology. I think this has to continue, because I think the most dangerous situation (is to) "follow that traffic". I don't know who he is. I can't positively identify who that airplane is. Yet I have to see and be seen. And I have to be able to maintain some kind of separation. If one fellow is on left base leg and I'm on right base leg and he says follow that airplane to the airport, I'm not good enough. I don't know I've got three miles or two miles. When I start reading the logo, I think I am getting a little close. So, I believe this has to go on. I believe you guys are right on track with this. I think TCAS is ancient. I think this is the way it should be done. I like to see the traffic myself in the cockpit. And your display was wonderful. You showed me where the airplane was. And at least I can do that. So I believe we have to do it just like this. I think TCAS has to go, and I think ADS-B has to be at least the initial answer to it so that I have a display of who's around me. And eventually, FANS 12 will be here. And we can go all the way back to the Wright Brothers. This is the way we started this in the first place. You don't have to look outside the cockpit. You look inside the cockpit and see the same thing. So Thank you. I appreciate it.

Brad Perry:

I'll just make a brief comment here. We've had a number of visitors come to Langley within the last year or so and some of these individuals are very distinguished. They took a look at what we are doing with our AILS research and they said, you know, this is better information than pilots have in today's VFR environment. I think Rocky (Stone) built on this in what you were talking about. The fact that if someone is closing on you, how soon do you pick it up with the unaided eye looking out of the window. And particularly in today's approach environment having to do the visual search because it's not on the instrument panel in front of you. Do you have to turn and look significantly aft of your position and that's a horrendous cross check if you have to do that sort of thing. So, it's significantly about the business of putting the right information in front of the pilots for this critical phase of flight. And there are many decisions yet to be made, but obviously giving the pilot what he or she needs when they need it is part of the central success story here. To keep it simple, we don't want a technology display in the cockpit beyond what is necessary for safety and operational enhancements as we have been talking about today. There in lies the challenge. Doing it as successfully, optimally as we can.

Trent Thrush:

I'll speak for myself, but at least for our approach, we are not looking at replacing TCAS. We're looking at enhancing the capabilities of TCAS, maybe within the next generation of TCAS's.

But, some of the comments I got from the pilot subjects in my study were a real appreciation for TCAS. Knowing more about what's out there and having experienced that TCAS has benefited them. So, there is a great trust built in TCAS from experience and also their training. If we can leverage that in so way for newer technologies, I think that would benefit us.

Brad Perry:

Yeah, In a global sense it's what do we do to complement or further enhance what's already out there. The fact that TCAS was not designed nor implemented for the specific terminal area problems that we're addressing here gives rise to the need to look further at what does make most applicable sense.

Ralph Nicosia-Rusin (FAA/New England/Airports):

First, I think the technology is very exciting. Just the whole concept of gathering data out of the cockpit and putting it into the surveillance system whether or not it ends up being pilots separating themselves or something integrated with the controller environment, it all seems to be a major enhancement to the surveillance of aircraft. Also, I think the pilot-based systems do speed up the response times with very convincing demonstration in simulation. The one concern I have with that is that you are perhaps over investing that data base in the cockpit. I guess there is a need to look at equipment failure, ... what type of standard operation procedures you will develop in response to equipment failures, and how aircraft monitor each other for the performance of their equipment. The question I had is or the suggestion I also had is regarding approaches. (I'm) fighting hard to develop capacity to airports like Logan and very happy to have independent parallel approaches. (I would) be just as happy to make improvements with dependent parallels. I would suggest that you might look at that especially as an intermediate step to provide you that additional margin of safety you might get. We might even be looking at perhaps 1-mile diagonal separations between the two streams. Probably brings you down to minimum runway occupancy times to both of those runways and still gives you very safe distance if you do have a blunder. So, I suggest that is another area you might look into. Thank you.

Perry:

Okay. One of the challenges with spacing airplanes is how can you best do that with today's ATC tools. Said another way, what accuracy can you achieve in paired or staggered spacing with the capability that's out there today. What's going to be available in the future. Obviously, CTAS is looking to implement an active FAST, (Final Approach Spacing Tool) capability which will greatly enhance the capability overall to pair up airplanes and to do so much more precisely than can be done today in the manual ATC environment. All that has to be taken into account appropriately.

Perry: Further comment on that from the panel?

Scanlon: Can we ask a question?

Perry: Sure

Scanlon: Is there anyone from NATCA here or one of the controller unions? I would really like your comment from a group like that as to what they have seen and are we so far off base that NACTA would never accept any such thing or just general comments would be nice to hear.

William Johannes (Technology Representative, NATCA)

It's very interesting. There are improvements that can be made. Off the top of my head, if you are talking about 1200 feet, 1700 feet separation, I think you are dreaming. I don't think the equipment that we have to work with will support that. And, the road we are headed down with the SR and other things, we are not going to have that capability to support it. But, we are always open to new technology. As far as TCAS is concerned, and I like to address the gentleman who flies the DC-8, TCAS isn't going to go away. I can tell you that. We support the use of TCAS. We

believe it improves safety in the system. There are some bugs in it, but its come a long way in the last 5 years. Right Rocky (Stone). A few gentle pushes.

But I think you are going down a track to improve what we have to work with. But I would suggest you learn to crawl before you try to take big leaps down to the third of a mile separation and do this.

Ran Gazit (Stanford University)

I have two comments. First of all, the studies that were made at Langley assumed that GPS is used for both navigation and guidance through the approach and for the surveillance through ADS-B. And that means that if an aircraft is blundering due to some GPS failure ... it also would not be able to tell that it is blundering. So there is some integrity issue that you should look at. And another comment is that all the simulations ... involved a human in the loop. And although I understand the importance of that, it seems that this limits the number of simulations that you can make and therefore the statistical significance of the results which were presented here is poor. And if you like to look at the acceptance of the ideas which were presented here, you should look at the false alarm rates of those systems. In order to do that you need to make more simulations, probably in the form of a Monte Carlo simulation. So the results that were presented here can be used to tune in models of human reaction into those Monte Carlo simulations in order to get more statistical significance results regarding the false alarm rates.

Perry: Comments on the statistical basis and significance of our research.

Scanlon: Of course the false alarm rate is very important and that is something we do want to look at. Monte Carlo simulations, we have Rockwell Collins for example has run statistical studies for us and so has MIT. We started out down that approach, but you are right, we sure need more varied type approaches looking into the different scenarios rather than just the few we have used so far. As far as monitoring the equipment when you have equipment failures or when the differential GPS is off, we really haven't even looked into that. I guess we view that more as an industry type thing than what we should be doing. Maybe we should be into that, I don't know.

Rocky Stone:

With the GPS accuracy and the differential GPS, or when it fails, I think that in SC-186 we are very sensitive to that issue because we realize we are combining a navigation and a surveillance function into what traditionally has been two independent functions. And because of that, we have defined, we used to call it, actual navigation performance. We now call it (the) position uncertainty factor. But essentially, what we are saying is that GPS and DGPS can have errors, but ... we can within the GPS box detect those errors. And if necessary, coast or have another navigation source for the ADS-B position report. And when that happens, the ADS-B box has to be smart enough to say, I now have a much higher position uncertainty. And, if that kind of a failure mode would happen, during for instance, a paired approach, that would be time for the paired (approach) to be over and the escape maneuver to begin.

Trent Thrush:

Concerning the false alarm rate data of the system itself, I turn you toward Jim Kuchar as I mentioned before, and some of the reports and studies that he has already done. He has compared the false alarm rate of the system to the false alarm rate of TCAS. I think he is already kind of going in those directions, so far as the alert work that he has been doing.

Brad Perry:

Okay

Frank Cheshire (American Airlines, DFW)

Comment to question - We had a prototype CTAS at DFW in the TRACON for a period of time. The good news is in an advisory capacity it worked well; the controllers liked it. The bad news is when the prototype probation period was over, they took it out. The controllers did not like that.

Brad Perry:

Well that communicates significantly the fact that the enhancement provided by CTAS was in fact good. That is one of the basic measures of anything when you take it away - do you hurt? And you're saying that they did hurt.

Frank Cheshire:

My understanding was they had used it to good advantage in improving the runway loading balance at DFW. My request is, I suspect my boss sent me here because I'm the lowest common denominator in our office, and I'm going to have to be able to explain the charts that are in the proceedings and I would request that the rocketship include a detailed description of what each phase of the profile represents, what technology it is based on, and where there are transitions from one to another. The first time it appears in the proceedings if you would please.

Brad Perry:

Okay, we'll take that as an action and Charlie and Marvin will be working together to do that. That's a very good suggestion. I think that is required for the proceedings to be more stand alone overtime, with respect to the basis of the research, and understanding what we really did. The rocketship for our study was very crucial.

Comments:

Robert Jacobsen (TAP Program Manager, NASA ARC)

Just let me make a comment regarding CTAS at DFW - it isn't gone. I believe what you're referring to is a specific test program that was run where it became active for a day long period or 8 hour period and yes there were very good results, but the development work continues and at this point the FAA is committed, and I think they have plans ... if I'm not mistaken for implementation in eight airports around the country in the next 2 years or so, one of which is Dallas. It has been received very well. I just want to make a comment to follow up on something that you mentioned and embrace our NATCA representative that is here. We recognized the importance of the air traffic controller in the process of the airspace system and the procedures that are used. We want to encourage their participation in all the development activities that we have in all of our airspace system programs. I think our experience in CTAS has borne that out. Until we really got involved with the controllers and had them become part of the development process, you can take all the engineers you want and you're not going to solve the problem. They play a very key role in being part of the solution in CTAS and we want to make sure that that happens in other technologies as well. I think the AILS work has great potential, obviously huge pay back for those (situations) where it is applicable. We need the controllers to be part of the solution to that problem, but there is a big roles and responsibilities issue that needs to be addressed.

Jim Serrill (SeaTac International Airport)

We may be one of those airports where AILS is applicable. As I listen to the AILS discussions and look at the technology, it appears that we're solving only one dimension of the constraint and that's the lateral separation. The pilot looks out the window sees another airplane out there and in visual conditions judges whether there is closure. AILS does that during instrument conditions. The second constraint is wake turbulence and right now under visual conditions you run airplanes side by side and get 800 feet separation. You run them side by side and you're making parallel approaches based on the fact of using procedural avoidance of wake turbulence. That's based on the airplane in front of you being at or below you. Is there not a way within the AILS to add an

altitude parameter to that and some algorithm that based on the position says where that airplane can or cannot be and if the preceding airplane is above you that that then triggers a missed approach.

Charles Scanlon

I'm sure we'll want Dave Hinton to also comment on this. As a pilot I was very surprised at some of the research that they've come up with. For example: In measuring the wing tip vortices in Memphis, I was surprised to see one example where the wing tip vortex apparently descended slightly, hit a slight wind shear and went back up. It just blew my mind to think of a wing tip vortex going up and going above that airplane in front of me is the wrong thing to do. So I'm not so sure anymore that just flying above the other airplane is the solution after seeing actual wing tip vortices that go up. So that's the reason why we've asked the AVOSS (wake vortex research) people to help us. It may be that under certain atmospheric conditions, you just simply can't run closely spaced parallel runways. You may have to shut it down to one and only one. And if you had an answer, yes it is safe, (or) no it's not ..., you could shut it down or leave it up. That might be one of the solutions. At any rate, we're just now beginning to look at that problem.

(Unclear question from audience) Will that also ... under visual conditions?

Scanlon: Yes, very definitely.

Brad Perry:

Absolutely, as part of our wake vortex research we certainly will have a more complete and comprehensive understanding of wake vortex behavior under a wide variety of weather conditions. Today as most of you know, the Aeronautical Information Manual has some rather imperial rules-of-thumb to follow for safe distance and separation from wake vortices. These have worked very well for the most part, however, as Charlie mentioned we're gathering data now that shows that wake vortices don't always descend. Sometimes they descend, stop descending, and then descend some more. And it is through this much more complete understanding that I think we'll have capability to ultimately fly even more safely than we do today. And that's a safety dividend from the TAP and RSO efforts in addition to what we're doing to primarily to enhance capacity.

Dave Hinton (NASA Langley)

The wake vortex development effort that we're participating in will be able, when it comes to maturity, to be able to predict how the wakes are going to behave in the atmosphere, how far they will drift and how quickly they will decay. How that actually gets implemented in the AILS is going to be something that we'll have to work out together. It may be procedural or it may require some vertical dimension which Charlie you would have to comment on what the capability of your system is. I can't do that. We will be able to determine, given atmospheric conditions, (whether) wake is going to be a consideration for the (parallel) approaches.

Frank Hansen:

I too would like to tell the gentleman from Air Traffic Control that there are some of us who feel that this is probably going to evolve into a combination of systems and we personally believe that there is a role for the air traffic controller, particularly, in the monitoring phase. In fact, I think we would welcome that, at least through a transitioning period and probably forever. Jim and I flew the simulator yesterday and I haven't flown for several years in an airliner, and I've never flown a side stick controller or that horizon. And outside of being kind of sloppy, I did manage ..., in a matter of seconds, to initiate a go around. I think we're over emphasizing that whole problem that we have there. I think back about 30 years of check piloting, when I taught literally hundreds of guys about 100 foot decision heights with big airplanes where you came down and you trained in 100 feet, which isn't very much left to go, ... (that) you punched the button and you went around.

So I think it is a relatively simple procedure that Charlie is pushing there that all you got to do is push the toggle button and turn 45 degrees and it's a piece of cake. I think we're putting too much emphasis on it. It is something we need to address and we should continue to. Now, kind of the same thing on the vortex turbulence in the fact that we know that we have hundreds, maybe thousands of airplanes every day. All you have to do is to go to LA or anything that lands wing tip to wing tip grounded visually. They're not falling out of the sky, they're not crashing or anything. We know that it causes turbulence and I think you've got to look at the record. Go out and run some tests if you want to look at these airports. Any of us who have flown into Washington National, O'Hare, LaGuardia know that these places are wing tip to wing tip lots of times. So granted we have some big problems, but I don't think we need to make them bigger than they are. I think Charlie is right on this missed approach procedure. I don't think a missed approach is any big deal one way or another. I would like to commend the fellows here. This is wonderful to see this kind of work. I have copies of our SeaTac position because we're like a lot of other places where we proposed 1800 feet because if we went to 2500 feet, we would literally go over the cliff. And that takes 23 million yards of dirt and probably 300 million dollars. This is a big problem. Bill Cotton from United said we're never going to fill San Francisco Bay. So we've got to be realistic about where we are and what we're trying to do. I think we can do it all and with the help of these guys very successfully.

Paul Miller (Safety, Chairman - UPS Independent Pilot Association)

One of the questions that I have is that when TCAS was first started, it kind of started with congressional mandate which led to an FAA regulation and was further amplified with a second regulation which brought the TCAS requirements to ten-seat airplanes. And somewhere in that mix the address the two or three hundred airplanes that UPS has, the three or four hundred airplanes that Fed Ex has, we're just left out of the mix. So the United airplanes, the American airplanes, they're flying in and out of Philadelphia, DFW, and San Francisco. I'm in a 74, 3 miles behind you at flaps 25 trying to get to the runway as fast as you, basically looking out the window to make sure that I'm keeping 3 miles because I don't have TCAS. I can do that at night pretty good, but then again I'm only 48 and my eyes are pretty good. But somewhere down the line, when I get the requirements to wear glasses, I'm going to be looking out there and seeing the lights of Philadelphia and say... "Looks like 3 miles". And when I take that ride with the FAA guy, he's going to have a block that says V1 cut, but he's not going to have a block that says "Can see 3 miles". Yet, there is a procedure that says "Fly 3 miles". So what we have here is a big disconnect. We have an FAA failure to put a regulation into effect that would require the TCAS and AILS and all other technology, yet you've got FAA integrating these airplanes right into the mix without any differential, including the Jurassic DC 8's. And that's why he was talking about visual because that's the only piece of instrument he has. So you really do have a problem. And as you know, our pilot association petitioned the FAA for a TCAS requirement, ...I'm sure it will be a long lead time before anything takes place. So this is an issue that should be addressed as well as the technology. You have to have the requirement to institute it. Without the requirement, it will not be instituted.

Brad Perry:
Comments on that?

Unclear tape segment ... comment made.

Paul Miller (Independent Pilot's Association):

I didn't really mean to start any discussion about whether or not freighters should have TCAS and I really didn't mean to imply that I think that TCAS shouldn't happen. ... So, I believe that all aircraft should have TCAS. They all should have TCAS that they will use, can use, and that they can afford. I believe that the technology for what we call TCAS today is just ridiculously expensive for what you're getting. You're getting no bang for the buck at all.

I believe that if you give me a cockpit display and some way of telling me to turn to avoid this guy and give me some better tools than what TCAS has to offer,

I want to see it in a 172. It needs to be in all the airplanes. And Since GPS will be in all the airplanes and there is no doubt in my mind that the United States Government is going to save billions of dollars once GPS is in all the airplanes. There's a major incentive. And once GPS is there it's a real short distance to ADS...(recording not clear). In any event, I just didn't want anybody to misunderstand me, that I was against TCAS. I think TCAS is wonderful, but I think TCAS as we know it today just is not getting it done. It's not good enough. And it is limited to the big boys who have big bucks. They are the only ones who can afford to put it in. If we can't get it in the Twin Beaches, historically it's the twin Beaches, those aircraft that have caused mid air collisions. I mean, when is the last time two airliners got together. I think it was Las Vegas somewhere over the Grand Canyon. It was a Constellation and a DC-7. So, TCAS isn't going to help a lot if we put it in one kind of airplane, TCAS has to be in all airplanes. And I think that GPS, ADS, FANS-12, if you will, technology is where we have to go. And we have to go fast. ...(We are getting to into the)... AILS business because it's going to save bucks, therefore its going to be pushed. AILS to me is just a stepping stone toward an intelligent TCAS. I don't care about parallel approaches. It doesn't mean anything to me. I care about the other traffic that's around the airport when ATC tells me you are cleared for a visual. Ten miles visual scares the XXXX out of me. I don't know who is out there. The controller says, do you have the airport. And I say yeah. He nods off to sleep. He's done. His responsibility is finished. Now I have to do it. And that spooks me.

Rocky Stone (UAL):

I want to respond a little bit to that. One of the things we are trying to do in SC-186 is be very sensitive to that (as) we want to design an ADS-B system. We want to make specifications for an ADS-B system that will be affordable for every user. And that means the Cessna 140 owner, the Piper Tripacer, and in fact, we are putting provisions in our MASPS (type of RTCS standards document) for parachuters to carry ADS-B units so that we can tell when they are coming through our flight path, I guess. The point is we want to make a system that has the potential of being very inexpensive and yet that has the reliability and the continuity and availability of the signal to be very reliable, and to be something that the pilot will use and trust in. And that's why, and I appreciate the freighter and the fact that you guys are not under the TCAS mandate, I think there are good things and bad things to be said about that. And in fact, you may have lucked out by waiting for the next step in this technological evolution. You may get most of the benefits for and order of magnitude, ... less price than those of us that have TCAS.

Robert Jacobsen:

I just wanted to make one comment on that, not to get into the TCAS argument one way or the other, except to... But it brings to mind one thing that in our development of any further technology in this area, is that we have to bare in mind that there is a mix in the fleet. So we have to address, from a procedures standpoint, what is going to happen.

And this is another area where air traffic control has to involved with us in the development of these procedures because not everybody is going to buy. And consequently we are going to have air traffic, if we follow the scenario that was presented today, we are going to have some folks out there determining their own separation, but yet we are going to have a system where ATC is going to have to determine separation for other aircraft. How is all of that going to work? It's a big procedures and human factors issue. And so we have that to address if we are taking this thing forward as well.

Leonard Credeur:

I had one sort of story that I preach here. If you would indulge me for just a minute. You know, in this whole issue, I think a couple of people talked about this. In terms of AILS, there are kind of two approaches to look at this thing. One approach is to look at it from the standpoint of the

studies that have been done so far. Looking at separations and looking at response times, and seeing how far we keep airplanes separated from each other. That's sort of the approach of PRM, absolutely assuring separation. Just for philosophical discussion, we have another point of view. That is, if you were to take two airplanes 700 feet apart, coming in on a visual approach, and do a blunder, it would be interesting to see what the response time might be under that circumstance. And think about the relative safety of a situation like that versus perhaps some electronic lead information, coupled with an alerting system. Because, you know, I'm not a pilot myself so that maybe this is off base here but I think in talking to pilots, as they come in on a visual approach and they do a lot of things. Part of the scan problem is to occasionally look over there and see what the other airplane is doing. But they are also doing a lot of things in the cockpit. And what can happen is that the other airplane, between when you look out there and do your internal scan, a lot of things could happen. If you did experiments there, it would be interesting to look at it from that approach. There are really two kinds of ways to look at this thing. I'm just throwing that out for thought.

Lou Taylor (Honeywell):

A real quick question, I think you have been dancing around it, but there is a lot of analog aircraft out there. The demonstrations you did are very impressive, but they are all FMS EFIS. Will the DC-9's, 737's, 727's ... Do you have any thoughts on how to implement this in a non-FMS non-EFIS aircraft?

Charles Scanlon:

That's a very good question. Of course the work we have been doing is showing sufficiency. With these tools we are getting good positive results and the question is do you have to have those tools or not. In other words, if you take the round dial airplane with possibly a glass TCAS display, and audio and get the same results. The answer is of course, we don't know. We haven't done that. However, in the first tests we did use the non-zoom-in capability versus the zoom-in capability. In other words, on that 10 NM range you got almost no information at all about whether the other airplane was moving in or not moving in. And it turns out there is statistically no difference in the miss distance, the bottom line. So, about all they had was the turn climb and the flashing on the primary flight display. So, it may be you could implement something in a round dial airplane and get it going. We don't know the answer to that. We have not shown...(recording not clear)...necessary. Just that we do have sufficiency for at least the results we have for the miss distances. But that's a very good point. Thank you.

Anon:

The PRM and AILS are supposed to be complementary systems. Are PRM descending escape maneuvers still part of the PRM equation?

Gene Wong: I believe it is. Let me explain it this way. It is going to be the last resort as far as the air traffic control system is concerned. We recognize a descending breakout is not really a natural maneuver for pilots because they have been taught to do the breakout, to apply power, pull up and turn. So, in our procedure development for the controllers (Rudy please join in to help me out. Rudy is our representative from air traffic.) We would try to minimize that escape maneuver, but the air traffic system retains that option, as a last resort option. There might be some special geometry that you may need to do the descending breakout. For example, the intruder aircraft is descending, and maybe one way to escape is to do a descending breakout for the evading aircraft. The air traffic controller would know all of the particular circumstances underlying that particular encounter. So, that would remain one of the ATC techniques. But my understanding is that it is not an optimum technique.

My friend that says that a missed approach is a routine procedure, it sort of takes it out the routine when that one time in a thousand you get that one time you get a descent and every pilot will hit

the TOGO switch, you have the throttles going forward to go-around power, now you have to descend.

You're setting yourself up for some real interesting evolution, especially with a dirty airplane that's light ... I think that's an equation for disaster.

Perry:

Okay, we have time for one last question

Clark Dodge (Regional Commission Airport Affairs, Sea-Tac)

One of the things that I'd like to throw into this equation is a little political aspect. I'm the President of the Regional Commission Airport Affairs. We are trying to look at ways that airports across the country including Sea-Tac can benefit by the work that's been done here. I think it's time now for all of us to get together and maybe form a coalition between the technology standpoint and the political, financial. Everything we can do to help NASA in what they been working on. There are a lot of gentlemen up here that have presented various aspects of what we can do. Those of us that are sitting in this room also have something to add to this. Brad is graciously offering to be a clearing point for a lot of this and I think now is the time, all across the country airports and airport owners/operators, aircraft owners/operators, the airlines to really get together and say what do we need, and how we get there, and how can we get there quickly. Because if we keep postponing this and study on the study on the study, pretty soon the technology we are working on right now will have already have passed us up, and we won't have accomplished anything. The same thing will happen for the next evolution.

So my challenge to you is let's work together and Dr. Scanlon, I appreciate your help on this matter. I was very impressed with what I saw. And don't quit. Let's keep going. Thank you.

Perry: Thank you. Comments on that.

Perry: OK. I appreciate those comments Clark. We certainly want to move forward. There is a role for each of us to play and I think as we work together, we will surprise even ourselves at what we can do. NASA is in the conceptual research end of this and many other parties are required to make this real and operational. But, speaking with the NASA hat on, it is personally exciting when we see our research being noticed and being as applicable as AILS is in today's time frame. I think one of the best things that could happen from a NASA perspective is when industry takes advantage and moves out with our research to move it forward, through all the many hoops that need to be successfully navigated to make it operationally real. And, it is through working together that I think we can realize that. I share your comment about taking advantage of the technology before it passes us by. There's a challenge there. It's a challenge for each of us. We have to assume the correct roles and I think through working together we can be very successfully. Further comments on that?

Charles Scanlon:

I certainly would like to agree that a group of people like for example a SEATAC, avionics manufacturer, an airline could really form (I don't know if anybody is familiar with AGATE or not), but such a group as that could really, I believe, make a difference in actual implementation of technology. And so, I would certainly encourage, and I'm sure everybody up here (in the panel) would be more than willing to help with any such group that were formed. I welcome that comment and I hope anybody interested would contact Brad Perry for that.

Brad Perry:

Let's wrap this up, and in so doing let me say how much I appreciate all of you being with us today as we talked about an exciting area of research and development. I think there is clear potential here as many of us have shared. It is in part using a lot of things that already are there. Using them in a different way to do something different that hasn't been done before. That is truly exciting.

Appendix A



Airborne Information for Lateral Spacing

Workshop Agenda

October 29, 1996

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|--|-----------------------|
| 1. Welcome, Workshop Plans and Overview | (30 min.) 8:30 - 9:00 |
| Moderator Brad Perry | RSO Program Manager |
| Welcome Charles Blankenship | Dir. AST Program |
| Workshop Plans Brad Perry | RSO Program Manager |
| TAP Overview Robert Jacobsen | TAP Program Manager |
| 2. RSO and AILS Program description and overview | (20 min.) 9:00-9:20 |
| Brad Perry | |
| 3. NASA Research Preliminary Reports: | |
| LaRC 3400' and 2500' Study: Marvin Waller | (40 min.) 9:20-10:00 |
| BREAK 15 min. | |
| ARC 4300' and 2500' Study: Trent Thrush | (40 min.) 10:15-10:55 |
| LaRC 1700' and 1200' Study: Charles Scanlon | (40 min.) 10:55-11:35 |
| 4. Paired Approach Concept - UAL: Rocky Stone | (30 min.) 11:35-12:05 |
| 5. NASA Flight Tests Plans Charles Scanlon | (25 min.) 12:05-12:30 |

LUNCH Break and Demonstrations

- | | |
|---|-----------------------|
| 6. PRM status | (30 min.) 2:00 - 2:30 |
| Gene Wong, FAA AND-450 | |
| 7. Supporting Technology | (30 min.) 2:30 - 3:00 |
| RTCA SC 186 update (ADS-B) Rocky Stone, Chair | |
| Wake Vortex Issues David Hinton LaRC | |

BREAK 15 min.

- | | |
|--|-----------------------|
| 8. Wrap up: Participant Discussion and Input Session | (45 min.) 3:15 - 4:00 |
|--|-----------------------|

Demonstrations at the TSRV Simulator

4:30 - 7:00

Simulator demonstrations will be conducted during the lunch break and at the end of the meeting. There is a sign-up sheet at the registration desk.

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Appendix B

Compilation of the Workshop Evaluation Forms

Note: In the replies to each question the numbers refer to a particular responder. For example, all of the responses numbered "5." were responses from the same participant. Twenty six (26) forms were submitted.

Regarding the workshop -

Was it informative?

1. yes
2. yes, more time should be devoted to Q&A to challenge and discuss the ideas presented.
3. yes
4. yes
5. very
6. yes
7. yes
8. yes
9. very much so!
10. yes - very
11. yes
12. yes
13. Check mark presumably meant yes.
14. yes
15. yes
16. yes
17. yes
18. yes, very
19. yes
20. yes
21. yes
22. yes
23. very informative
24. yes
25. yes
26. yes

Did it accomplish what you expected?

1. more
2. yes
3. not sure
4. yes/no
5. yes
6. not very issue oriented
7. yes
8. yes
9. yes
10. yes
11. yes

12. yes
13. yes
14. to learn about AILS
15. yes
16. yes
17. It was different than expected.
18. (left blank)
19. Generally yes
20. yes
21. yes
22. yes
23. yes
24. yes
25. yes
26. yes

Why or Why not?

1. The program is further along than I envisioned.
2. It gave us a chance to have input with people who are conducting tests and models.
3. Didn't know what to expect
4. I would like to see the exact equipment requirements.
5. Understanding of new programs/technology.
6. Hard to tell what to do next after problems were identified.
7. We are trying to keep up with or get ahead of the rapidly change environment.
8. my objective was to learn more about RSO and AILS and I was definitely exposed to a great deal of input.
9. Gave a clear overview of the program, its objectives and current status and plans.
10. great overview
11. Good overall status presentation, good way to meet people working on these programs and get POC's.
12. Good overview of program and met people. The panel discussion was great. Simulators were informative.
13. (left blank)
14. (left blank)
15. Information on experiment
16. (left blank)
17. R and D of the concept has a long way to go to cover the issues and considerations that need to be addressed to be ready for "prototype" operational evaluation.
18. Very informative
19. (left blank)
20. (left blank)
21. Good presentations - Simulation was very informative.
22. Good overview
23. Topics well presented, professional manner and indicated thorough scientific methodology to achieve desired objectives.
24. Very good
25. NASA provided an excellent overview of their AILS research efforts that strongly suggest that substantial benefits can be derived by the flight-deck centered approach monitoring/alerting. There seemed to be considerable interest by industry members to pursue these technologies.

26. Very good enthusiasm and participation.

Regarding NASA's AILS Program -

Does it address the problem?

1. yes-but may not be only answer
2. yes - but
3. yes
4. yes
5. yes/no
6. no
7. yes
8. not yet
9. Only partially
10. yes
11. yes
12. Not for me to say - we aren't an airline or airport.
13. a good start! Needs to be an ongoing crosstalk between aviation interests.
14. (left blank)
15. yes
16. (left blank)
17. As far as it goes; the unanswered questions pose additional problems until adequately addressed.
18. Good beginning
19. yes
20. yes
21. possibly
22. yes
23. I believe it does
24. yes
25. yes
26. yes

Why or Why not?

1. There seems to be many potential problems that have not been address that could effect the problem.
2. Windshear (lateral), weather problems such as on adjacent
3. Gives cockpit control of traffic.
4. As long as the FAA allows this ADS-B in place of TCAS
5. Problem should be tied to cost benefit more clearly.
6. Traffic mix/fall back integrity
7. Trying to make a more efficient system.
8. Good outline - needs some holes filled.
9. Problem is fundamentally not technological but operational and institutional.
10. (left blank)
11. addresses problems that are concern for pilots, airports, airlines and FAA.
12. (left blank)
13. (left blank)
14. (left blank)
15. (illegible)
16. (left blank)
17. (left blank)
18. (left blank)
19. From pilots point of view.
20. (left blank)
21. (left blank)

22. (left blank)
23. (left blank)
24. The concern re parallel rwys is justified
25. A flight-deck centered approach makes the most sense, allowing fast response times.
26. Addresses specific aspects.

Suggestions for future direction

1. (left blank)
2. Thunderstorm or a storm moving across the localizer, needs to be brought toward the forefront of models and algorithms.
3. It should be used in lieu of TCAS
4. A projected timeline for completion
5. Compare safety versus cost.
6. (left blank)
7. Get traffic controllers involved
8. continued analysis and additional testing
9. Need to perform FMECA or blunder assumption and verify/establish data (surveillance) dependencies.
10. When AILS is beyond its concept stage, my Division would appreciate an overview of airborne equipment maintenance.
11. Should also look at parallel runway landings (staggered approaches)
12. (left blank)
13. Have another workshop when flight testing etc. warrant an industry update.
14. Need to look at relating false alert alarms that result in evasive maneuvers to reduction in capacity - meaningful quantitative work there. We have done a number of system studies at draper involving the development and quantitative evaluation of system FMEA's (Failure Mode and Effects Analysis). We would welcome the opportunity to pursue such an analysis for ADS-B/GPS system availability.
15. Integrate activity with FAA ATC organization.
16. (left blank)
17. (left blank)
18. ATC - Flight crew, equipment interface continue to keep aviation interests informed. Continue workshops.
19. Fly actual approaches - validate assumptions. Legal questions - control responsibilities.
20. Closer coordination with ground solutions, analysis of event probabilities in real world, analysis of effects of false alarms, analysis of evasions on ATC operations, other aircraft.
21. Need to examine local airport environment-obstructions to M.A. etc. Also risk assessment for safety with equipment outages - Aircraft need to monitor and tell pilot when other aircraft are not operating. Mixed environment to accommodate aircraft without proper equipment.
22. More on concept demos
23. Try to structure programs to distinguish between R&D and application knowledge.
24. Consider angular offset approach paths to provide more separation en route to the final approach fix.
25. (Left blank)
26. Would like some kind of necessary and sufficient aspects presented.

Interest in future AILS Program participation -

Are you or your company interested in participating with NASA in its future AILS Program?

1. yes
2. yes
3. yes
4. yes
5. yes
6. (left blank)

7. yes
8. yes
9. yes
10. It appears that it will be some time before the instructions for continued airworthiness will begin to be developed. AFS-300 (Acft. Maint. Div.) most certainly would like to participate with whoever will administer that process. (P.S. What is the impact of the proposed enhanced vision approach aids to AILS).
11. yes
12. yes
13. yes
14. yes
15. yes
16. yes
17. I am, my company probably is but I can't make that commitment.
18. yes
19. yes
20. yes
21. (left blank)
22. yes
23. yes
24. yes
25. Yes, we have enjoyed and learned from our partnership with NASA on AILS and look forward to continued participation with NASA to validate and enhance AILS and to contribute to implementation of a marketable system.
26. yes

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